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SIR JOHN HAWKSHAW, F.R.S., CIVIL ENGINEER.

FOR many months we have been reciting the lives of the army of distinguished men, connected with the railway world, which includes the men of science, the men of invention, the great manufacturers, the enormous development of English influence, which springs from the adaptation of iron and other metals, and the mechanical forces, to the service of mankind. The class of men created by this remarkable change, is an addition to intelligent humanity, for which all future ages will be grateful. The character of their works, the greatness of their conception, and the prodigious self-denying energy, that could not only defy, but invite obstacles for the very purposes of conquest, exhibit them as among the choicest specimens of our race. Thoughtful beyond what we designate as thinkers; self-reliant, beyond those we honour in commercial daring; and persevering, far beyond the tenacity of purpose which belongs to the warrior, they form a race that England is proud of, because the manifold riches of her kingdom find a manifestation in the creative powers of her children, who swarm over the whole earth, as witnesses to the beneficial greatness of the mother-land, and will continue to

produce works more excellent than those monuments their fathers have bequeathed.

Leeds has the honour of being Mr. Hawkshaw's birth-place, for he was born there in the year 1811. His education at the Grammar School of that town, was of the usual elementary, practical, and learned character, which for its basis took the ancient lines, and for its future regarded the events and tendencies of the present. Railways were then making headway in the scientific world, and enterprising lads selected the novelty in preference to the old road of ordinary commerce. Young Hawkshaw resolved on making that his specialty, and became, on leaving school, a pupil of Mr. Charles Fowler, who had a high reputation as a surveyor, and a fine business in road making throughout the West Riding.

This occupation enabled him to acquire much knowledge of roads, bridges, canals, and all means of communication; but before he reached the age of twenty he relinquished that for the position of assistant in the office of Alexander Nimmo, who held several important government contracts for works in Ireland, but he had not been in his situation more than a year before his principal died, and the business required young Hawkshaw's utmost energy. The firm had some heavy copper-mining operations in South America, and thither he was despatched with indefinite managerial powers, and a serious responsibility. He had earned the regard of all of his associates and patrons, by the uniform character of his life and conduct; and their selection of him to be their representative conduced to their interests, and very much assisted the mental development of the engineer. There had always been an intelligent expressiveness of style in his correspondence, that evidenced an acuteness of mind, loving to know all things which happened to come within his range of observation; and this visit to South America led him to his first and only venture in book-making, "Recollections of South America." At that time the little publication possessed interest, for the subject had the charm of novelty, and the treatment of it by a juvenile gave additional freshness. It is flowery in style and somewhat diffuse, but his after life showed, that his work there had a powerful influence on his character, and affected his choice in the matter of future occupation. In a few years he returned to England, and entered into an engagement with Mr. James Walker, one of the oldest of our civil engineers, who was so much in the confidence of government, as to be consulted by them on the feasability of George Stephenson's plans for applying steam power to locomotive uses; and he had also a high reputation as a Dock Engineer: besides these distinctions his name stands at the top of the list of Presidents of the Institution of Civil Engineers. Hawkshaw continued his relations with Mr. Walker until 1837, when he accepted an appointment as agent to the Manchester and Bolton Canal Railway, which very speedily brought him the like engagement in the Manchester and Leeds Railway, a line of 50½ miles, from which has grown all the Lancashire and Yorkshire wonderfully successful undertakings, and which owe their great works, in embankments, viaducts, bridges, and tunnels, to the constructive genius of this eminent engineer.

He had become a member of the Geological Society of London, and it happened that his first contribution to the literary store of that excellent and useful body, is upon the works on the first of these undertakings.

When excavating for the Manchester and Bolton Railway in 1837, Mr. Hawkshaw found five fossil trees erect beneath a small bed of coal of two feet thickness, underlying a common strata of 50 feet and among coal strata of varying thickness much disarranged. These had a coating of coal, and are described in detail at page 173, Vol. I., Geological Society's Transactions. The largest had a circumference of 15 feet and 11 feet in height. He regarded the thin covering of coal as the vegetable strata, which covered the trees after the convulsion. His experiences in South America availed him in investigating the phenomenon and its probabilities, and he has been remarkably correct in his general opinion; he believes these fossil trees to be what the name implies, that they had lived where they were discovered, but it is impossible to assert of what kind the specimens were. He inclined to the opinion, that coal deposit is not the result of decayed trees, so much as decayed vegetable matter analagous to our peat; he had observed in America much vegetable decay produced by the fermentation of juices, rather than what we might describe as dry rot.

The construction of the Huddersfield and Sheffield Railway is the work of Mr. Hawkshaw, and the separate operations are deserving of special notice. The traveller ought to be more mindful of the scientific energy and skill that provides him with invaluable aid than he is: he can, if he please, observe the triumphal labours of the engineer in rushing through a country of hills, valleys, streams and ravines, and in despite of every natural difficulty and hindrance, witness the exemplification of that power which can reduce nature and nature's forces to obedience and the service of man. The Paddock Viaduct at Huddersfield has a length of 1,040 feet, and a height of 84 feet; it consists of 15 stone arches carried over the Huddersfield Canal, the river Colne, the turnpike road to Holmfirth, and the premises of a large mill. These arches are of 30 feet span; there is one cast iron bridge, at the south end of the viaduct 47 feet span, and 4 central openings each of 75 feet span. The four central openings are crossed by six continuous longitudinal malleable iron lattice girders, 340 feet each in length, supported on stone piers, and made fast to the central pier, but resting on plates, to allow for contraction and expansion. Four girders are above and two below the rails.

Mr. Hawkshaw had commenced in 1846 a large work, of a similar description, at the village of Lockwood near Huddersfield, for the Huddersfield and Sheffield Railway. Here his line lay at almost right angles to the ridges and valleys, and it was necessary in the 14 miles between Penistone and Huddersfield, to make five tunnels and four viaducts, the lowest of these last being 80 feet high. This at Lockwood has thirty-two arches each of 30 feet span, and two oblique ones, of 45 and 70 feet. The total length is 1,428 feet; height, 136 feet to top of parapet, and 122 feet from the bed of the river to the rail level; the width is 28 feet. Its masonry is remarkable. He obtained the stone from the cuttings. It is a hard flat bedded sand-stone from 3 to 12 inches in thickness, but as the stone varied in thickness, he adopted a novel style. All the arches except one are made of these irregular stones and hence a 12-inch is built in with 7, 9, 5, and 3 inches, necessitating the best skill in the trade, and the best mortar that could be made. There existed considerable doubt of such work being durable, but there it is, and the rapidity of the trains has not done any harm at present. The foundations are on slate. The quantity of masonry is 972,000 cubic feet, and the cost of the work was £33,000.

Another at Denby Vale on the same line is singular from consisting of two stone arches having been built at the ends, and the intermediate parts being of timber, supported on stone foundations, of about three feet height from the ground.

The Cannon Street, Charing Cross, and London Bridge Railway is another of his great works, and his name suffers some discredit, as well as much renown, in connection therewith. Nothing could well be more ugly than the great bridge which spans the entrance to the station; without question, it is of a vast length, and probably required extraordinary skill, but it has left an impression on the public mind, that however the engineer may tower above many in mechanical genius, he has a very faint perception of the beautiful. So of the eigeteen stone arches that carry the line over the Surrey streets. They might have been a little ornamental without increasing their cost. But the Charing Cross Bridge is acknowledged to be the lightest, strongest, and cheapest of its kind, and those who witnessed its building, will remember the gradual disappearance of Hungerford Suspension Bridge, as the new structure rose out of the water. That Bridge has gone to Clifton, but the piers of Brunel in the Thames still sustain the railway—at least in part. This bridge is 1,360 feet in length; has a width of 50 feet between the girders; footways on either side of 7 feet in width; and a clear headway above high water mark of 25 feet. From the Surrey Side to the pier, the bridge is carried on a series of hollow cast-iron cylinders or columns; from the Middlesex side to the other pier, the space is built on for the Station and Hotel and the subway. These columns are 14 feet diameter, and are sunk into the bed of the river, from 30 to 40 feet, until they rest on the London Clay, and then filled up with solid masonry. This bridge cost £160,000, and was opened on the 11th January 1864.

England owes to Sir John Hawkshaw her recognition of the wisdom and possibility of the Suez Canal. In antagonism to Lord Palmerston and to his friend Sir George Stephenson, he maintained the idea of a unity of water-level, and this also as against the French Engineers. He wrote, "Again and again engineers and others have made misakes from not knowing what has gone before them." In the early stages of the Suez Canal project the objection was the existence of 32½ feet between the level of the Red Sea and the Mediterranean. Laplace declared it could not be, because the sea average over the globe never could be various. The idea of such difference belonged to past ages, when Darius conquered and thought he should drown Egypt by cutting the Canal, not knowing that very long before his time, there had been a course through that region. Archimedes, said Strabo, asserted that the force of gravity is diffused, so far as the sea is concerned, over the whole earth, and that there could not be a difference in level. The mind of Hawkshaw is essentially reverential to what has gone before, knowing that, as in the case of electrical typhony, Sir Charles Wheatstone possessed all the elementary knowledge, so he, in his more limited sphere, was

able to employ his great scientific repute in opposition to the absurd but universal belief, that the Mediterranean would be drained if the Red Sea were attached. Such notions belong to an age of superstitions. Because the Red Sea happened to have been the road of the ancient Hebrews, there is no physical law, or reason based thereon, to suppose it lower than the European Sea. Sir John Hawkshaw happened to perceive the absurdity of such prejudices and such *lack-of-faith*, and he declared that the Suez Canal was possible, and thereby differed with Sir George Stephenson. The course of waters is now flowing without any swell or interruption. Lesseps, Hawkshaw, and many others are vindicated by the unanswerable argument of well-deserved success. Lord Palmerston's political opposition is now among the few blunders of his career, and Hawkshaw's sympathy with the enterprise is honoured. His judgment, at a critical moment, gave inspiration to a doubtful case, and the European world will ever recognise the boldness and the acumen of his scientific genius, in connection with the large-hearted policy of the Khedive.

Those in authority at Cambridge in 1869 felt the force of his remonstrance concerning the sanitary arrangements of the town and river. "The Cam is called a river," he writes; "practically it is a canal. Its waters are unprovided by locks above and below, and are nearly stagnant. The whole town drains into it . . . Stench so horrible, no one ought to be allowed to row on it. To acquire or retain physical vigour by rowing on such a river would require the suspension of the laws of nature." He also declared, that the deepening and widening would soon be useless, and that Mr. Bazalgette had long laid before them a design for intercepting the sewage, at a cost of £27,000, in a town of 37,000. It was a vigorous attack from one who knew what he was talking about.

Upon another occasion, he addressed the public, by a letter to the Duke of Argyle, then Secretary of State for India, complaining of a calumnious statement issued by the officiating secretary, alleging that "the governor-general is given to understand, that in the civil engineering profession in England, it is a recognised practice for civil engineers . . . to receive, in addition to salaries, commissions and other pecuniary considerations, and that such a practice is considered legitimate." These statements Sir John Hawkshaw promptly and peremptorily denied, as one long professionally engaged on Indian Railways, and for the honour of his profession.

The idea of communication between France and England under the sea is as old as time and engineering, and many provincial and visionary theories were rife in 1873, when Mr. Hawkshaw propounded his Channel Tunnel scheme. Mr. Austin, Mr. Low, and a dozen others, could be mentioned as claimants for the honour of such an idea; but none of them produced any thing beyond a mere scheme that had no guarantee. They had no design; no investigations; no deep borings; no facts. Hawkshaw had been carrying on his practical life in his own way, with entire ignorance of all their schemes or desires. He designed, he investigated, he bored, and he brought facts that made a Company. Surely there can be no question of his claim to the honour of making Channel communication underground; somebody questioned his claims in the *Times*, Dec. 5th, 1873, and Hawkshaw answered on the 8th, that he had seen no design of anybody's, nor any suggestion but what was held in common, and while repudiating Low's claims as regarded himself, said frankly that no one could "claim to be an inventor of a Channel Tunnel." Hawkshaw's invention has the peculiarity of not only boring the earth, but of providing artificial ventilation in working the engines. Therein he excels, and is indeed alone, in the rivalry of projectors; which rivalry is absolutely ended by his appointment as engineer: an appointment that will confer on him eternal renown, if, as we have every reason to believe from the past, his fore-cast is clear.

The Bill for authorising this great work and granting the concessions, appeared in the French House of Assembly in January 1875. It covenanted, on the part of the Government, to permit a sum of £400,000 to be spent in experiments, within five years, provided an English Company could be formed upon similar principles for the English side, and that the whole work should be completed in twenty years. To these terms Lord Derby made no objection; and Hawkshaw, on the part of England, and Lavally, on the part of France, became jointly the engineers. These gentlemen had known each other intimately when the Suez Canal was in hand, for Lavally held the position of General Contractor to that great enterprise. M. Lesseps introduced the Bill on the 20th, and described the main features of the scheme. The Tunnel is to be 30 kilometres long, with ten metres of land-tunneling on each side for approaches. As before said, the idea is not new. M. Thome de Gamon suggested it 35 years ago, and is still living in very humble circumstances. The House of Assembly insisted that all the arrangements for tariffs should be written and filed, but they are of no interest to us, and most probably will be modified when wanted. The Report possesses an historical interest in itself; it is interesting also to us who are now reviewing Sir John Hawkshaw's career, but the particulars are too long for recital: they would require a separate article.

Sir John Hawkshaw occupied the President's Chair, at the Bristol Meeting of the British Association in 1874, and delivered an address on the history of Mechanical and Civil Engineering and Architecture. He occupied a prominent position at the time, in relation to the Channel Tunnel, and the omission of that topic caused much disappointment among the audience. Professor Herbert, in the Geological Section, took up the question, by arguing that in consequence of anticlinal ridges running under the Channel, parellel with it and at right angles, it would be impossible to construct the Tunnel under the Straits of Dover otherwise than in a circuitous direction. Sir John replied to what he termed the general reasoning of Professor Herbert, but stated that he had taken means to ascertain, as nearly as it was practicable, what was the condition of things in that part of the Channel, and dissented from the conclusions before them, and described what had been done; first in geological inquiry, by carefully measuring to ascertain on each side the outbreak of the beds which lay underneath, and said it appeared from the geological map, from St. Margaret's Bay, and Sangatte would be suitable to carry the tunnel through the lower chalk; to verify this, an examination was made across the Channel by dropping from a steamer a weighted instrument in 500 places, the apparatus running with great velocity to the bottom and bringing up chalk. This corroborated what had been done before so far, and if it were necessary, in constructing the tunnel, to follow the circuitous line pointed out by Professor Herbert, it would never be constructed at all—only in a straight line. People found that the tunnel would be near the water, and thought any small error would affect its construction, but the deepest point of the Channel in that part was 180 feet, and the tunnel is intended to be 230 feet below the bottom. He had had to do with tunneling below the sea, and knew the difficulties to be encountered. The current was so strong there, that the bottom was washed quite clean, and their experiments proved the absence of any deposit. As to the question of ventilation, people seemed to assume that they would construct a tunnel into which nobody would go. There would be great difficulties, such as the conveyance of men and material, but this might be provided for, by the introduction of pneumatic tubes on each side of the Channel; and assuming the tunnel to be made, they had only to exhaust the air from the tube by an aperture in its centre. Ventilation presented no difficulty: he had been silent about it, because as an engineer he had found the professional rule to be good,—not to speak of works until they were performed, and generally to avoid discussion in the process; when the tunnel is made, the method pursued would be evident to every one. Of course, much would have to be learned by experiments and experience, but the evidence was sufficiently conclusive to his mind to induce him to enter upon the undertaking.

At the Bristol meeting, Sir John Hawkshaw received from Mr. Topley a corroborative opinion in favour of the successful carrying out of the scheme, and also in the general world Mr. Topley elaborated the same views in the Quarterly Journal of Science, April 1872, and Popular Science Review for October 1874. There is the antediluvian story about a land bridge, between Dover and France, which scientific men who love rhetoric and type affect, but Mr. Topley, after describing W. Austin's plan of 1853 (which went to Boulogne and has had much favour), and the subsequent plans, concludes by recognising Hawkshaw's deep borings through the chalk as the only safe method of attempting the tunnel. It was well he did so. Sir John Hawkshaw had a position and a history, which placed him far above complimentary or adverse critics, and knew more of his subject by study and by instinct than they. He needed not their flattery, and as a science devotee could wait for results.

The great changes in engineering since the introduction of railways are numerous, but that of steep gradients is about the boldest. This is Hawkshaw's idea, and he did not have far to go for opponents when propounding it. Men like George Stephenson resented the attempt to develop or change the dictum laid down by the old engineers. There was no overflow of courtesy, when Stephenson denounced the broad gauge, and described the atmospheric sytem, on which Brunel had spent large sums, as "the greatest humbug in the world;" but when Brunel turned on him and said he could drive an engine safely, at the rate of a hundred miles an hour, he created a feeling of personal antipathy, which Stephenson never lost. The same would have been Mr. Hawkshaw's fate, had he ventured to tell the old school that gradients such as that at Farringdon Road Station and

Ludgate Hill were possible. The young engineer persevered in advocating his theory, and ultimately proved that such a method was much to be preferred to the old alternative of making circuitous routes. His views are now unchallenged and adopted.

But Sir John Hawkshaw's influence reached beyond England. He has made a great many railways here, but when the history of railways is written, his name will be found occupying one of the most distinguished places in the construction of Indian and Russian lines, and as consulting engineer to those in the Mauritius. The recital of these would be mere repetition, and therefore unnecessary. The career is one of unchecked progress, and when Mr. J. Meadows Rendel died in 1856, there was no alternative but to place the subject of this notice at the acknowledged head of his profession, as he was already so in fact. From that time his labours have been confined, or almost so, to the carrying forward of the great Government works of our own land, either as engineer-in-chief to the Government Harbour of Refuge at Holyhead and the works connected therewith; or, in the great operations at Spithead, for the defence of Portsmouth Harbour, originated by Lord Palmerston, and carried forward during that statesman's life with all the energy of his clear mind.

W. S. C.

THE SALT MINES OF INDIA.

OF the 750,000 tons of Salt consumed annually in India, less than one tenth (68,500 tons) is derived from the Salt mines of the country, although these are fully capable of supplying the entire demand, and are in fact inexhaustible. An increasing quantity is imported from Italy: a considerable quantity from Great Britain—Cheshire; and some small portion from miscellaneous sources. Salt is placed under the head of finance in all Government Reports, because from it is derived the greater part of the revenue. It is an article of prime necessity, and bears a tax of 6000 per cent. on the prime cost: a tax which leads to smuggling, and has to be guarded and collected at as heavy cost. The supply from the mines is by far the best in quality, but on account of the heavy cost of transit, it cannot be sent over the entire country from thence; much is produced by evaporating sea water, and some from brackish water in various places, saline efflorescence, &c., and from the water of the Sambhur Lake; which is situated in Rajputana in the States of Jaypur and Jodhpur under 27 degrees latitude.

We will notice these in order. First, the Sambhur, or, as in Keith Johnston's Atlas, the Salt Lake, second, the Mundi; then the Kohat; and lastly, the Salt Range known as the Mayo mines.

The Sambhur Lake is really the large drainage basin of the surrounding country. When full it is 32 kilometres long and 8 broad, and extremely shallow. The bed sinks so gradually from the shore to the centre, that for several months in the year the water has not a depth of more than one metre in the centre; while on the contrary after the heaviest rains, when the lake is full, the maximum depth is scarcely three metres.

The methods of producing salt at this place are of the most primitive description, but the quantity realized is very great. Spontaneous evaporation is the process, and the annual production 45,000 tons. Artificial banks are made all round the lake, and the salt crystallizes over the entire surface. In these banks are perforations that conduct the water of the lake into artificial basins all round, when the principal one has, by reason of heavy rains, become full; and evaporation proceeds there as in the parent lake. The soil is spongy, and there follows percolation; but from that source the natives gain, by constructing other receptacles, and then by the ancient methods of irrigation, raising the water and sending it back for proper evaporation.

Dr. Warth made several analyses in the winter of 1869-70, with these results:—*a*, brine from the lake itself; *b*, percolations from holes in the lake bed; *c*, the water left after the first crystallization had been gathered:—

	a	*b*	*c*
Chloride of Sodium, . .	22.4	18.2	19.7
Sulphate of do., . .	2.1	2.5	7.7
Carbonate of do., . .	0.4	0.5	3.1
Water of do., . .	75.1	78.8	68.7
	100.0	100.0	99.2

The following is the analysis of 3 samples of crusts, which were formed in the process of salt manufacture, and of course represents the waste:—

	a	*b*	*c*
Unsoluble substance, . .	1.8	0.8	2.0
Chloride of Sodium, . .	24.5	9.5	18.1
Sulphate of do., . .	57.0	74.1	57.5
Carbonate of do., . .	11.0	12.8	10.6
Water of do., . .	2.4	1.2	10.0
	96.7	98.4	98.2

The smallness of the quantity of water in the first two samples, shows that Sulphate of Sodium can crystallize in an anhydrous state, from saturated saline solutions, without the aid of artificial heat; an interesting circumstance. And it is worthy of observation, that in the liquor left after crystallization there were traces of bromine, but none of iodine or of nitric acid.

Second, Mundi Salt. Mundi is a small state, having a town of the same name on the river Beas. Near it is a range of hills extending northerly as far as 32 degrees latitude, which is called Gokar Ka dhar, on the west side of which there is rock salt. There at the present time two mines are in full work; one at Guma, 1,500 metres above the sea level, and one at Drang, at 1,000 metres. The exact geological relation of the salt to the rocks between which it occurs is not yet ascertained. The main ridge consists of non-fossiliferous highly metamorphosed clay slates, with a small quantity of limestone, perhaps triassic. The eastern base of the ridge is formed by the valley of the river Ol on the left, on the eastern bank of which are found mica schists, which contain the magnetic iron ore, used by the natives in the process of iron smelting. Still farther eastwards, are the higher elevations of the Himalayas, where granite and other crystalline rocks abound. To the west is a succession of parallel ranges of the tertiary strata, that intervenes between the salt outcrops and the great plain. The salt is covered throughout by a soft friable mixture of clay, angular debris, limestone, quartz, and other materials, and is called *Lukhan*. It appears in several places on the western side of the ridge, and there are many brine springs which evidence the presence of salt unseen. The length of the tract occupied by the salt mines, the Lukhan outcrops, and the brine springs, is 25 kilometres. The Lukhan strata is from 3 to 12 metres in thickness, and ordinarily of purple colour, although other tints of black and white frequently occur; apparently it is the residence of dissolved rock salt, and there has not been found, singular to observe, any trace of gypsum whatever, although that is almost universally present in all other such deposits. The salt obtained at these mines is on the average mixed with 25 per cent. of the substances that constitute the Lukhan,—clay sand, angular debris, red and blue limestone, and quartz up to a thickness of three centimetres; peroxyde of iron, small rhomboides of dolomite, and now and then iron pyrites. The mines are under native management, which is extremely defective; there is no underground mining, and in the surface-quarrying the debris is so sparingly and unsystematically removed, that the lives of the workmen are greatly endangered, and the supply of salt rendered very precarious. Although the demand for Mundi salt does not exceed 5,000 tons a year, the supply is less than the demand in consequence of these defects of administration.

Dr. Henry Warth, the Collector of Salt Revenue, notes his surprise at finding a plan common to European salt mines adopted in these remote Indian provinces,—that of water-cutting. For this method there are special facilities; fresh water is abundant, and the resulting brine can flow off of itself, or can be made to do so by the simple machinery for lifting and transferring it, or by hand labour. The admixture of hard pebbles and sand renders pickaxe cutting impracticable, and the action of water in lieu thereof is of great service. The known thickness of the salt layer does not exceed 12 metres, but no one has cut entirely through them; but from the fact that masses of pure salt are found embedded in the midst of what is ordinary, the plausible suggestion is that in all probability there are whole beds of better salt deposited at greater depths, notwithstanding that no tradition of such circumstance exists among the native population.

Third, The Kohat Salt-region, which is south of the town of Kohat, on the right side of the river Indus in lat. 30, 33, 30 degs. and extends over a tract of country 70 kilometres from E. to W. and 15 to 30 from south to north, of very uneven formation, at a height of 500 metres above the level of the sea, where are several parallel mountain ridges of the height of 1000 metres and more. Nearly the whole of the district is barren, only a few towns and villages existing in the neighbourhood, of scattered patches of arable and cultivated land among the

desert of rocks. The geology is very simple. Rock-salt forms the lowest known stratum; then follows gypsum, bright red-clay and nummulitic limestone; after these endless strata of more recent tertiary clays, sands, and conglomerates. The salt is exposed at the hill ranges, where the whole beds have been raised at an angle of 45 degs. in some cases; but, of course, the base of those rocks has never been explored. The thickness of the salt at the outcrops in the Bahaderkhal quarries exceeds 300 metres; at other places the minimum thickness may be stated as low as 50 metres, and in these the colour is grey and very little stratified; but in the uppermost layers an impregnation of bitumen gives a dark-brown or black colour.

Rock-salt has no foreign elements in its composition, nor even an efflorescence of sulphate of magnesia, or any such substance, and its ordinary colour comes from an admixture of bluish-grey clay. A rough analysis is subjoined of the Kohat produce, and was made at Calcutta:—

Sample of ordinary salt from Bahaderkhal.

Water and earthly matter, . .	0.45
Chloride of Sodium, . . .	97.00
Sulphate of Calcium, . . .	2.55
	100.0

and proves that if there were any foreign salts present they must be in very small proportion. Most of what is taken from the quarries in that region is of good quality, but there are places where so large a mixture of clay and gypsum prevails as to render the product unfit for sale; and unfortunately no distinction can be made beforehand between the good and the bad layers. At Bahaderkhal, where the formation is of enormous thickness, there are some distinct layers of bad salt: everywhere the bed is covered with a layer of gypsum of from 3 to 10 metres in thickness, which spreads far and wide beyond the visible outcrop and it must therefore be an open question whether the salt follows the gypsum continuously or whether it be limited to tenticular isolated masses. Above the gypsum lies the dark red-clay, and then comes the nummulitic limestone of a thickness varying from 20 to 100 metres.

The number of these salt outcrops is very great here. Dr. Warth's estimate gives it as 350 distinct ones, having an exposed salt-surface of 300,000 square metres, of which the largest is the quarries at Bahaderkhal, which lie in a salt valley of the width of 6 kilometres, and half a kilometre in width. The western half of the valley is composed of salt entirely; a brine stream flows through the valley over a bed of rock-salt, and two hillocks of the same that rise 70 metres above the bottom of the valley. These are all surface quarries. But besides these are four others in the district, of which Jatta and Malgin are the next of importance. That of Malgin involves heavy profitless toil, on account of the accumulation of debris that has to be removed being as great, if not greater, than the quantity of salt acquired. There are also real mines that have been excavated beneath the surface.

In the Kohat district two methods of excavation are employed; one, the old method, does not require the aid of gunpowder, and the other does. The former is adopted at the Bahaderkhal quarries, and the salt is taken in large slabs of 10 centimetres thick, and measuring 33 centimetres at base, each weighing 22 kilogrammes. Much skill is manifested in getting out these slabs. The rock is soft, and long channels are easily cut with the pickaxe over the surface in parallel lines, across these are other parallel channels drawn, intersecting the others at right angles, and leaving rectangular spaces of the size of the desired slabs. All round the allotted bulk of rock the parts outside these lines are driven off by means of hammers and wedges until the desired size is obtained, and then the bulk is split by the same means in the exact line of stratification, which line the native can readily detect, and the slab is produced without waste. The advantage of that form is that the trader can load his cattle more readily for the purpose of transit, and the size suits best the convenience of market transactions and general habit. When powder is employed, a larger yield of salt follows, but at the disadvantage of being most inconvenient in shape and size. Traders refuse to purchase the small pieces that slip through the packing-nets, and the others are too large, or too shapeless, for ready transit. The packing nets being made of palm leaf (*chancerops pichiena*) are strong, but must be used with care to avoid their rapid destruction. The trader refuses altogether those pieces which are under the weight of 5 kilogrammes.

This accumulation of debris and the occurrence of waste are serious drawbacks to the workers, who only get paid for the quantity of saleable salt they can collect, and have to do their own clearings without pay. Labour is almost the only capital of those who live by mining produce; and hence many devices have been created. Where there are many of those heaps or tracts overlying the soil, the miner will commence a new excavation, and as the strata is at an angle of 45, he begins his shaft upon that incline. The decline thus formed serves for a path to the bottom of the working, and the overhanging portion also yields material. When this shaft has been worked to a sufficient depth through the salt, a belt of debris is removed to the depth of two metres on the overhanging side, and the debris is thrown back into the former excavation. When the salt is reached, the same belt of two metres' thickness is continued into the stratum. The overhanging wall of debris and the remaining wall of salt form together an arch that is quite safe, and the debris used to fill up the former excavation is firm, because it lies upon a slope. When this excavation has reached the desired distance, the work proceeds in renewed concentric arches, the excavated space being successively filled up by the debris removed from above the salt surface. It is not difficult to perceive that these operations are of the crudest character, and that the waste is enormous.

The total quantity annually yielded in the entire Kohat district is 18,500 metre tons; a most inconsiderable yield when compared with the vast deposit; the exposed salt surface of which is as above estimated at 300,000 square metres. The annual quantity washed off by surface rain must be fully as much as the annual sales; and another waste of the same extent is caused by the dissolving agency of percolating water, which results in brine springs all over the region.

The area over which we must suppose the existence of salt is certainly prodigiously greater than that at present exposed. At Bahaderkhal alone there are three square kilometres; and all over the district we must assume that there are 11 square kilometres more, thus making a total of 14 square kilometres. Estimating the thickness of this layer at the moderate figure of 60 metres, there results an actual stock on hand sufficient for 40,000 years at the present rate of supply and demand. But we shall assert that the salt is limited to centricular masses. It probably extends over the entire area that is covered by gypsum, and close to the surface.

East of this district is the Punjab Salt-range. It forms the northern boundary of the great plain of the Punjab, and stretches from near the town of Jhelam on the river Jhelam, or the ancient Hydaspes, to the town of Kalabagh on the Indus, over a distance of about 250 kilometres. The highest point occurs in the middle of the western half of the salt range: this is Mount Sakesar, which rises 1500 metres above the sea, and about 1300 above the neighbouring plain. Elsewhere the height of the range varies from 600 to 1000 metres above the sea. The chief part of this salt range consists of a plateau which commences at Sakesar and runs westward, almost to Jelalpur, where the range forms still high but narrow mountain ridges. The greatest breadth of the salt-range occurs some distance east of Sakesar, where it reaches 15 kilometres. All along the southern side it ends more or less abruptly by steep acclivities to the plains. On the northern side there is a less distinct boundary between the plateau or the high ridges of the salt range and the successive lower ridges, or high ravine country north of the range. The salt crops out at the base of the southern acclivity and in numerous transverse gorges, which wind their way from the top of the salt-range to the plain in the south: only at two places, near Nurpur and Namel, does it show itself on the north side. Salt is the lowest member of the geological formations that build up the range: the highest of these are the younger tertiary sands, clays, and conglomerates, which cover the whole of the ravine country to the north, rising up also along the northern flank of the range appearing now and then at the top. These contain bones of mammals, and some of the sandstones are full of petrified wood. This strata of sandstone and petrified wood occurs also in the upper tertiaries of the Kohat salt region.

The nummulitic limestone is the next lower formation, and covers most of the surface of the salt range plateau: the escarpment of the steep southern acclivities of the range is, as a rule, formed of the massive walls of this limestone, which is very rich in fossils. Besides the nummulites there are echinites, oysters, nautile, and common univalve shells in great quantity: below are beds of lignite and alumshale: the former is found in the eastern, the latter in the western half of the range, but both are of the same age.

A distinction has to be made between the western and the eastern half of the salt ranges, with regard to all the following strata, down to the salt formation. In the western half, below the alumshale, are found successive strata of ferruginous sandstone, dolomite, and limestone, which two last contain a great many fossil shells, *productes sperifer*, goniatites, encrinites, &c., and belong to the carboniferous period. Below these are found the purple marl, and gypsum overlying the rock-salt, from which it is evident the salt belongs to a period prior to

the coal formation. In the eastern half of the salt-range are the following strata from the tertiary lignite to the salt, viz.:—first, olive-green sands, with conglomerates of well-rounded boulders of granite and other crystalline rocks. One of these boulders has been found which, at its smallest diameter, is one metre: further down is a thin-bedded strata of clay and sandstone, with casts of salt crystals: below this, a hard greenish-yellow coloured dolomitic sandstone; and still further down, dark shales and flags which contain the only known fossil of the entire series,—a small bivalve of the genus obolus. Finally, purple sandstone forms the transition to the gypsum and salt formation. The transition takes place with great regularity: there are no signs of any interruption having taken place between the formation of the salt and gypsum and the immediately succeeding strata; and we therefore assume that the latter, like the salt itself, belongs to the Devonian, or perhaps even the Silurean, period.

Peculiar to the salt-range is a rock of an extraordinary bright-red colour—a mixture of clay, red oxide of iron, and selenite. This red gypseous clay, as Dr. Warth describes it, is in some places as much as 100 metres thick, and in others is almost wanting; as a rule it overlies the grey massive gypsum and the salt, but here and there it contains nests or even thicker beds of salt. Towards the eastern end of the salt-range, at Mount Jagi Ka Tilla, the Chambal ridge, and near Jelalpur, the massive grey gypsum is the only member of the gypsum and salt formation that crops out along the base of the hills. Here there is no proper red gypseous clay, but the salt is indicated by a few saline springs. At Jutana is the most eastern outcrop of rock-salt; from thence, these are repeated westwards at short intervals until 15 kilometres beyond Kalabagh. The whole length of the line of outcrops is not less than 200 kilometres, and an idea of their number can be formed from the fact that 600 guardsmen are required to protect them against the smugglers, who dig salt to evade payment of the duty demanded by the government who owns these mines.

Just as has been observed concerning the Mundi and in Kohat salt regions, the rock-salt bed at the Punjab has never been worked through, and therefore the lower strata is not known. The grey gypsum which overlies the salt at the range is continually cropping out wherever the situation will permit, and Dr. Warth affirms that the grey gypsum forms a continuous member of the whole geological group. The rock-salt appears so often, and sometimes at short intervals, and there is nowhere any proof of its absence that, as far as he can say, there is very strong probability of its being continuous. Until further evidence is adduced, he would express as his opinion that salt occurs in separate thick lenticular layers that are very often connected by continuous thinner bands, or by rows, of salt nests. These salt outcrops contain much impure salt mixed with clay, or they are inter-stratified with red gypseous marl: and it is only at the quarries and mines that we can know what salt layers really are. While the outcrops contain only banks of pure salt of less than one metre in thickness, the mines show a continuous thickness of pure workable salt of 50 metres.

There is nevertheless considerable difference in the various mines. The richest is that of the fourth—the *Mayo* salt mines—which are situate near the village of Khiurah, or Keora, and are called the Keora Mines by the traveller Burnes. Here are four seams of thoroughly pure workable salt, and the following is the formation downwards:—

Red gypseous clay and massive grey gypsum, with enclosures of pink gypsum, limestone banks, &c.,	60 metres.
Bad and mixed salt (estimated).	50 „
Good salt,	8 „
Bad salt,	3 „
Good salt,	30 „
Bad salt,	15 „
Good salt,	16 „
Bad salt,	32 „
Good salt,	16 „
Unknown,	— „
Total thickness of the formation,	230 „
Total thickness of good salt,	70 „

The total thickness of the salt strata is, as far as at present ascertained, 170 metres; but there has not been a corresponding development farther west.

The next large mine, called Warcha, is 100 kilometres westward of the Mayo Salt Mines, and the supply depends upon a pure salt layer of only 6 metres in thickness. At the next place of excavation, 60 kilometres farther west, the Kalabagh quarries—banks of only one metre thickness—are utilized, and the greatest thickness of the worked beds is but 4 metres. The beds are, however, numerous; and the total thickness of the visible strata is at least 70 metres. Some parts of the thick layers of pure salt at the Mayo Salt Mines are quite compact, so that marks of stratification are discerned with difficulty. The rest is, however, subdivided into distinct bands of from 20 to 40 centimetres in thickness, and are of white or of light-pink colour in the middle, a dark-red at the outer part. The lines of separation between these bands are often denoted by a thin film of clay impregnated with sulphate of magesium. One feels inclined to attribute these bands to the annual growth of the salt-bed, but they are not quite sufficiently regular to make the hypothesis certain. Thick salt layers also exhibit some irregularities; at one place in the Mayo Salt Mines the layer of bad salt which separates the 30-metre layer from the 16 below, improved so much that the whole thickness of 61 metres was found to be worth excavating; at another place in the mine, a layer of bad salt, or salt clay, a few metres thick, and hitherto unknown, was found separating the lower portions of the 30-metre layer from the upper ones. These changes show that the formation of the salt deposit was influenced by local circumstances.

Another strange incident is the occurrence of foreign salts in the very midst of the salt formation; between the two lower layers of 16 metres of good salt, appeared a bed, one metre in thickness, of anhydrous sulphate of magnesium and potassium, and pure chloride of potassium. The bed thinned out after a hundred metres length, and there was no longer the chloride of potassium. It is very remarkable that the diposition of these foreign salts took place *before* the whole of the common salt beds had been formed, and not at the end, as was the case at Stassfurth. In the good 16-metre salt layer, above the potassium salts, a crack was perceived covered with crystals of bloedite. In the good 16-metre layer below the potassium salts, a similar crack was found clad with glauberite, a double sapt of anhydrous sulphate of sodium and calcium. No banks of gypsum nor of anhydrite are met with in the mine. Anhydrite is very rare; Dr. Warth only found the real substance once, and then in small yellow crystals, grown upon some gypsum at Kalabagh. In the red gypseous clay about the Mayo Salt Mines he found nodules of sulphate of lime, with 7 per cent. of water—a kind of semi-anhydrite. In the Kohat region he only met it once. He found a few clear crystals of the mineral at the salt quarries of Malgin in the gypsum which overlies the salt. Along the whole of the salt range are numerous remains of old superficial salt excavations and of old salt mines.

The number of works has been reduced to three for the sake of better supervision and administration. The annual output is approximately as follows:—

Mayo Salt Mines,	37,000 tons.
Warcha, do.,	4,000 „
Kalabagh quarries,	4,000 „
Total salt range,	45,000 „

We must take into consideration that almost the whole of this salt is consumed by the people, or in part by their cattle; scarcely any of it is used in manufactures. Dr. Warth estimates that about fifteen millions of people consume the whole produce. It is of excellent quality, and could not possibly be improved by any refining process; it is used in the natural state. When pulverised, it loses the pink colour and turns perfectly white, but, as the traders much prefer their supplies delivered in large pieces, the pulverisation is not effected at the mines, for, unless the pieces are of the weight of 100 gramm, they are thrown away as waste, and it is economy so to do, for otherwise they would lose much in transit and storage.

Before the year 1849, the date of the commencement of British rule in the Punjab, the mines were worked in a very rude fashion. Excavations were made without proper care for supporting the roof; the work had to be stopped during the rains, and the miners were pleased when large masses fell during that season from the roof, and thus saved them further labour. They did not use powder, but detached the blocks of salt by the use of wedges; the crooked entrance-drifts, which led to the interior of the mines, afforded no proper ventilation, the salt was all brought out by hard labour on the backs or heads of the workpeople. The work was so laborious that an early traveller, Burnes, an eyewitness, says, "That the sight of them was a piteous spectacle; mothers with their babies, children, and old people, were all alike occupied in bringing the salt to the daylight, and their death-like aspect, and ragged clothes, demanded the greatest commiseration."

The mines thus referred to by Burnes were what are known

Fig 1.

as the Mayo Salt Mines, and the management now-a-days is changed altogether, and for the better. They are situate in a salthill close to the southern base of the range; this hill rises 200 metres above the adjoining gorge, and consists, from top to bottom, of salt and gypsum strata. The different layers of good and bad salt have already been enumerated, and it only remains to state that these layers are not in a horizontal but in an inclined position, especially the upper layers. There are still large old excavations remaining, although they decrease continually, owing to the tremendous falls which occasionally occur. These old excavations are now connected in the interior of the hill, and as tunnels lead into them from places of different level at the outside, a natural circulation of the air is maintained, and the empty spaces are well ventilated. In the hot weather strong currents of cool air rush out through the lower tunnels, whilst air enters from outside into the upper ones; in the cold weather the opposite results are obtained. The new workings are in fact the continuation of old ones, but they are laid out in a modern and improved form: they extend over the three large layers only; the uppermost of eight metres thickness has been left out for the present. The 30-metre layer has a very steep incline to the north-west at an angle of 60 degrees; the next, the 16-layer, is less steep, and bends round above at an angle of only about 30 degrees; the lower 16-metre layer is at a still less incline, and indeed in some places is quite horizontal. A system of parallel lines has been drawn on an imaginary plan through the whole of the salt layers vertical to the stroke; these lines are alternately 8 metres and 14 metres apart. Vertical plans are imagined as laid through these parallels, and the spaces of 8 metres breadth between the verticals represent the pillars or walls of salt, which are left standing to support the roof: the spaces of 14-metres breadth are for the purpose of excavation. A tunnel of 700 metres in length enters the salt-hill from the bottom of the adjoining gorge in a direction that intersects consecutively the two 16-metre salt-layers and the 30-metre also. This tunnel has an incline of 1 in 75, provided with a line of rails of 0.75 metre gauge, from which are drifts that lead to the workings on both sides. The height and depth of these workings is limited by two horizontal plains, one at 15 metres below, and the other at 45 metres above the average level of the main tunnel. From tunnels driven at the top of the intended chambers, horizontal excavations of only two metres height are first commenced, and when these are extended over the whole space that is enclosed between the parallel pillar-walls and the upper and lower boundary of the salt seam, the floor is worked down.

In this way large chambers are excavated in the 30-metre salt layer, having a height of not less than 60 metres, commencing at 45 metres above and ending 15 metres below the rail-tunnel. In the smaller layers, especially at a small incline, the vertical extension of the chambers cannot be so great, because the underlying stratum of bed salt is soon reached; as a rule, the top workings are therefore continued in the smaller layers, in a slanting direction, in order that they may proceed with the layer, and therefore admit of long galleries being excavated.

The miners' families, who formerly had to carry the salt from the interior of the mine to the surface of the hill, are now occupied with the far easier work of bringing the salt from the workings to the loading stations in the tunnel; and, by the aid of these carriers, it is possible to work the mine with such great differences of level in one storey with only a single line of rails.

Every two or three months the cubical enlargement of each working is measured, and the gang of miners who have been occupied thereupon are paid accordingly. The payment is four shillings—two rupees in Indian coin—for one cubic metre of excavation in the head-workings that are only 2 metres high; the ordinary work of excavation downwards is paid at the rate of 2s. 3d. per cubic metre; for these wages the men have to excavate the salt, remove the waste, get the produce carried to the line of rails, procure their own tools, powder, and oil. The transport of the salt on the rails from the interior of the mines to the depot, over a distance of 2,500 metres, costs 6d. per metrical ton. The full trains run out of themselves, and the empties are pushed back by the workmen. One cubic metre of excavation yields, after the losses as waste, small salt, bed salt, and damage caused by rain, only 1,500 kilogrammes of saleable salt.

The total cost of 1,000 kilogrammes delivered at the depot is thus 2s. 6d. The price which the traders pay, including the duty, is £8, 5s. 0d. in silver. This duty is 6,400 per cent. Verily we must hope that before long a revision of the salt tax will be possible in the interests of the poor population of that magnificent empire.

W. S. C.

COLONIAL AND RIVER LOCOMOTION.

IN noticing the contents of the South African Exhibition last November, we pointed out the necessity of adapting our splendid examples of machinery to the crude conditions of colonial life, on the grounds of economy and adaptability. The machinist and the engineer have a boundless and very profitable field in endeavouring to make available the many labour-saving contrivances possessed by old and civilised countries, to the circumstances of new and undeveloped lands. The firm of Messrs. Alexander Wilson & Co., of the Vauxhall Iron Works, Wandsworth Road, S.W., have recently made two valuable contributions of the kind we have referred to, and will assuredly find their venture profitably encouraged. On pages 71 and 73 will be seen drawings—one, a light-draught paddle-boat, fitted with patent engines; the other a patent paddle engine for river steamers. These will be found most valuable aids in the commerce and intercourse of such countries as Africa, Egypt, and India, where populations are sparse, and trade is not vehemently in a hurry.

Boats are as well built in the locality where they are useful as if they were imported. Indeed, boat-building is an art common to man in his wildest state; and man, the animal, shows a keen instinct in contrivances belonging to his boat as to shape, construction, and comfort.

Fig. 1 (see preceding page) shows a native boat fitted for general communication in the island of Ceylon, where it plies continually between Colombo and Negombo, and having in the centre one of the patent engines made by this firm. We know, by almost weekly communications from travellers and explorers, the advantages of water highways in these unknown regions. Rivers and lakes, of which at home imagination fails to construct a correct idea, abound; water is plentiful, and its courses are comparatively direct. This is one of the many compensations in nature which sets off the inconvenience and loss that must otherwise have been endured from the want of roads, and the existence of vast swamps, huge woods, and arid deserts. The greatest part of these rivers are shallow and broad: hence native boats must not be so made as to draw much water. An ordinary steam engine would be too heavy on this account; and because of this circumstance steam propulsion has not been applied to river boats hitherto. Manifestly the advantages will be immense, from the facility they provide for traversing the small and shallow streams that intersect those regions, so full of natural resources now wasted or useless.

This kind of boat is used as a passenger steamer, ferry-boat, or tug. Its length is 60 feet; beam, 9 feet; light draught forward, 18 inches; aft, 20 inches. The load-draught, with 75 passengers on board, is 21 inches; forward and aft, 24; and its speed is 10 miles an hour. We have before had occasion to notice that in applying steam to local traffic in rude districts, wood is almost always used in preference to coal, because it is nearly impossible to obtain coal, and because any quantity of wood can be had anywhere and at all times for the trouble of cutting. The quantity is of course much greater—about twice and a half or three times that of coal to attain a given amount of power. As after a while coal will be deposited on the shores of the large rivers or on the coasts, these little light engines will be made much lighter, because the necessary extension of surface required for wood fires will be greatly contracted when coal can be used, and while the weight is decreased the draught of water will also be much lessened.

This engine (Fig. 2) has two high-pressure cylinders 7½ inches in diameter, of 18-inch stroke, and a boiler such as is used in a locomotive, only with the extra-large heating surface already mentioned for wood burning. The boat in Fig. 1 is of composite construction, the frames being made of angle iron sent out from London, bent to the required shapes, and then the planking is done in the country by the native workmen. As the engine and boiler are independent of the boat in their construction, a very small quantity of skilled labour is enough for fixing, putting the parts together, and connecting the feed-pipes for the pumps.

A patent paddle engine (Fig. 2) for a light-draught river steamer must be so formed that the centre of gravity of the machinery shall coincide with the centre of displacement, so that the boat may float on an even keel; the paddle-wheels must be near the middle of the boat's length in order to facilitate its being moved in either direction; it must be in the middle in order that there should be no necessity for ballast; the whole must be light, and it is finally important that the hull should be relieved from any undue strain of the engines.

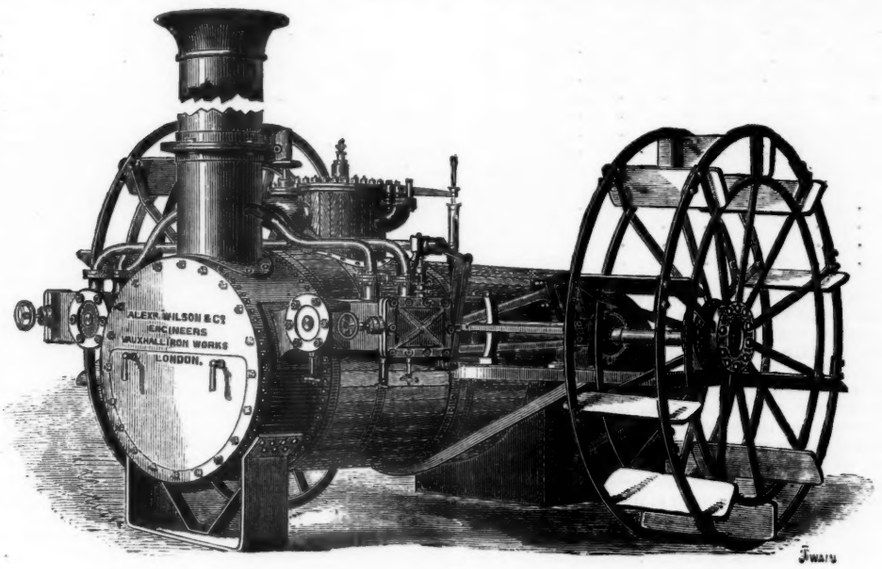


Fig 2.

Messrs. Wilson & Co.'s engine complies with these requirements, which render it in fact a river locomotive. It can almost be lifted in one piece, with steam up, and placed in its boat ready to depart. The boiler is of the same kind as that of a locomotive, and has an enlarged fire-grate and heating surface, in order to burn wood or cocoa-nut husks ; but some are made of a small size adapted to burn coal and of cylindrical tubular form. The cylinders are on each side of the boiler at one end. As the centre of the paddle wheels would be too high if the shaft was carried over the top of the boiler, and too low if beneath, it is passed through the barrel of the boiler by a cross tube or by a pocket let in from the top. The framing that carries the crank shaft and paddle bearings consists of angle irons bolted to fastenings riveted to the boiler, and arranged so as to be almost independent of the hull. The engines are fitted with link-motion reversing gear, worked by a lever placed conveniently near the stock-hole. The boiler has two small auxiliary pumps. This is fitted with two expansion valves, but a recent improvement has simplified that portion of the work.

In speaking of this class of machinery as specially adapted for the service of colonial settlers, we must not be supposed to limit the area of its usefulness. It is quite within the probabilities of the future that these little steamers will become popular on some of the larger estates, as these are connected by canals with rivers, lakes, and the ocean. The patentees have rendered an important service to the land proprietors at home and abroad, and we shall soon hear them commended more and more, and more and more rewarded.

WOOL DYEING.*

By George Jarmain.

Lecture V.

THE yellow colouring matters which I have now to describe are complementary to those which I have already brought under your notice, as they enable the dyer to complete the range of colours which are employed in the dyeing of cloths, the colours of which are required to be fast and permanent in the sense in which I have used these terms.

We will confine our attention, at the present, to the following yellow colours :—Fustic, American bark, flavine, turmeric, Persian berries.

* A Course of Cantor Lectures, reprinted by permission from the Journal of the Society of Arts.

Fustic is the wood of a tree called *Morus tinctoria*. It is imported chiefly from Central America and the West Indies. It is known to the dyer under the names of old fustic and yellow wood. It is prepared for the use of the dyer as chipped fustic, rasped fustic, fustic extract. It is used extensively in all three forms. When the chips are used they are placed in a bag in the boiling water, in the same way as that in which logwood is used. Rasped fustic may be thrown into the pan along with the goods to be dyed.

The tinctorial principles contained in fustic consist of moritannic acid, a pale yellow crystallizable substance, freely soluble in water ; morin or moric acid, a crystallizable substance nearly insoluble in water. As moric acid is but slightly soluble even in boiling water, the moritannic acid is the principal available colouring agent in fustic. Fustic gives a yellow colour on wool which has been mordanted with chloride of tin, alum, or bichromate of potash, and olive green with a mordant of sulphate of copper or copperas. Fustic is rarely or never used as a self colour, but it is very extensively employed along with logwood and the red woods producing that infinite variety of shades of composite colours known as blacks, browns, olives, drabs, &c., for which it is eminently adapted. Dyed on wool, with a bichromate of potash or copperas mordant, it produces a fast and beautiful and permanent colour.

In the heavy woollen cloth districts, where pilots, beavers, naps, reversibles, fancy trouserings, and such like goods are manufactured, it is more extensively used than any other yellow dyeware.

Its use and modifying action on other colours, such as logwood and the red woods, are best studied by dyeing equal weights of mordanted wool or cloth with varying quantities of fustic and of the woods I have just named.

As examples of its modifying influence, I have placed before you samples dyed with the following quantities :—

Mordanted with two per cent. bichromate of potash ; boiled one hour.

Sample.		Fustic.	Barwood.	Logwood.
1.	Dyed with	60	0	0
2.	„	30	30	0
3.	„	60	30	0
4.	„	20	40	0
5.	„	0	60	0
6.	„	40	20	3
7.	„	40	20	saddened with copperas.

Sample.		Fustic.	Madder.	Logwood.
1.	Dyed with	60	0	0
2.	„	40	20	0
3.	„	20	40	0
4.	„	0	60	0
5.	„	40	20	3
6.	„	20	40	saddened with copperas

Sample.		Fustic.	Sanderswood.	Logwood.
1.	Dyed with	60	20	5
2.	„	60	20	10
3.	„	60	20	15
1.	„	80	10	3
2.	„	80	30	3
3.	„	80	50	3
4.	„	50	80	3
5.	„	10	80	3

Sample.	Fustic.	Logwood.
1.	60	5
2.	60	10
3.	60	20
4.	60	30

It will be observed that each of the red woods and madder imparts its own special tone of colour along with the fustic, and as the practical dyer has generally to dye to a pattern, it is almost useless to give any special formula for particular shades.

My purpose will be better served if I endeavour to indicate to you the specific purpose the dyer has before him when he makes a selection of the red woods to be used. As a rule, the different shades of brown are obtained by using more than one red colour, and sometimes three or four of the red colours are required in order to produce shades exactly like a given pattern. In my opinion there is no department of dyeing which requires such an amount of skill, and practical experience, and knowledge of the modifying action of colours upon one another as in the dyeing of the different tones of blacks, browns, and drabs; and it is wonderful to see with what precision some of our practical dyers can arrive at any particular tone or shade.

In the use of the red woods as modifying agents the following points should be borne in mind:—

1. Camwood is stronger, faster, and brighter than either barwood or sanders.

2. Barwood gives brightness and lustre, but lacks body.

3. Sanderswood gives a more yellow red than camwood or barwood. It contains more colour than barwood, but its colour is not so bright.

4. Madder gives the finest, brightest, and fastest colour; it contains more yellow colour than the red woods, but its red colouring-matter is superior to those of the red woods.

5. Sumac gives a fine olive-yellow shade to brown, and helps to sadden when copperas is used.

6. Logwood in small quantities, say one, two, or three per cent., saddens or dulls the colour of the red and yellow woods.

7. Cudbear has a brightening effect, giving a purple tone to colours.

Incidentally, I may mention a particular effect which is frequently met with in dyeing of wool. The tips of the locks of wool often take a deeper shade of colour than the remaining portion of the lock, and as the wool becomes thoroughly mingled in the processes of carding, scribbling, and spinning, to which it has been subjected preparatory to its final manufacture into cloth, the dyer has to take into account the effect which will be produced by such admixture of colour.

In cases of this kind, the general effect produced by the dye may be ascertained by teasing out in the hand a small sample, so that the whole is made as even as possible. On comparing this with the pattern, it will be seen whether the proper effect has been obtained, or whether some additional colour, and what colour, is required.

There is another effect which is often perplexing to a young dyer; the red and yellow colours have different affinities for the mordanted wool; the red wood colours partially displace the yellow colours. If wool, in the course of dyeing, appears to have received a sufficient amount of yellow, but there is a deficiency of red, and the dyer proceeds to add what he conceives to be a sufficient quantity of red to make up the deficiency and brings the goods up to sample, he will frequently find that he will then have on too much red and too little yellow. The additional quantities of wood required are added in the form of rasped or ground wood, which is well worked up with the goods, or a solution of the extract may be employed for the same purpose.

The following recipes are examples of the use of several woods which were found to be required in order that a particular shade of colour might be obtained:—

Tan Brown.

Mordant—

	Per cent.
Bichromate of potash	1

Boiled for one hour.

Dye—

	Per cent.
Madder	3·2
Fustic	4·8
Camwood	2·
Barwood	1·75
Sumac	2·2

Boiled two hours.

Tan Brown, redder shade.

Mordant—

	Per cent.
Bichromate of potash	1

Boil one hour.

Dye—

	Per cent.
Fustic	7·2
Madder	4·8
Camwood	2·8
Sumac	2·4

Boil two hours.

California.

Mordant—

	Per cent.
Alum	1
Bichrome	1
D.O.V.	⅓

Boil one hour.

Dye—

	Per cent.
Fustic	25
Madder	2
Camwood	3

Boil one hour and a half.

Dark Drab.

Dye—

	Per cent.
Camwood	6·5
Sumac	2·
Madder	2·5
Fustic	4·
Logwood	2·5

Boil one hour and a half. Sadden with 1 per cent. copperas.

Olive Drab.

Mordant—

	Per cent.
Bichromate of Potash	1

Boil one hour.

Dye—

	Per cent.
Fustic	10·
Sumac	2·
Madder	5·
Logwood	·2

Boil two hours.

Madder Brown.

Mordant—

	Per cent.
Bichromate of potash	1

Boil one hour.

Dye—

	Per cent.
Fustic	22·7
Madder	11·35
Logwood	1·13

Boil two hours.

Drab.

Dye—

	Per cent.
Fustic	1·7
Madder	4·
Cudbear	·1
Sumac	·8

Boil one hour and a half, and sadden with ·2 per cent. copperas.

Quercitron Bark.

Quercitron bark is the inner bark of *Quercus tinctoria*, another species of oak indigenous to North America. For the use of the dyer the bark is dried and ground.

The principal colouring matter contained in it is quercitrin, a glucoside which is capable of breaking up into a sugar and quercitin. Both quercitrin and quercitin are yellow colouring matters which, in their effect upon mordanted wool, act very much like the colouring matter of fustic.

In woollen dyeing the use of "bark," as quercitrin bark is frequently called, was introduced by Bancroft, to whom we are also indebted for the most original work on dyeing we possess in the English language.

The use of the bark is not so extensive as that of fustic, but it

may be used for the same purpose, though it does not give the same amount of body of colour.

Flavin.

A preparation of bark known under the name of flavin is often used, when shades brighter than what can be obtained with fustic or bark are required.

Flavin consists mainly, if of good quality, of the colouring principle itself, namely, quercitrin or quercitin; its colouring power is therefore far greater than that of bark. One ounce of good flavin is equal in tinctorial power to 1 lb. of bark.

The best qualities of flavin are imported from America, where it is believed to be made from the fresh bark, but there seems to be some mystery about its mode of preparation.

Flavin is used for the yellow part of scarlets and oranges, and for almost any colour where a good bright yellow is required.

The colouring matters of fustic, quercitron bark, and flavin may be described as fast and permanent dyes for wool.

Young Fustic.

This is the wood of the *Rhus cotinus*, a tree which grows in southern Europe and the West Indies. It is prepared in the form of chips for the use of the dyer. Young fustic contains an astringent principle and two colouring matters, a yellow and a red.

The name fustin has been given to the yellow colour, which possesses many of the characteristics of quercitron, but there are some slight differences. On wool mordanted with a tin salt it produces a fine and tolerably fast yellow orange. Its chief employment in woollen dyeing is for the production of scarlets and oranges along with cochineal, for which purpose it is extremely well adapted.

The two remaining yellow dye wares which I have to describe, on account of their loose and fugitive character, cannot be used with advantage for the dyeing of woollen cloths for men's wear. They are turmeric and Persian berries.

Turmeric.

Turmeric is the underground stem of *Curcuma tinctoria* and *Curcuma longa*, and is imported from India, China, Java, and Barbadoes. The Indian variety is the most valued. For the use of the dyer the stems or tubers are dried and ground to a fine powder. The powder has a powerful odour, and a strong aromatic taste. The colouring principle contained in turmeric is called curcumin. In wool dyeing, the use of turmeric is confined to the dyeing of a certain class of browns on stuffs, and is often associated with colours of a fugitive character like itself. It finds no use in the heavy cloth districts, and if its employment were altogether discontinued as a woollen dye material, it would be no great loss to the public who happen to have to wear goods dyed with it. It serves a useful purpose in the laboratory as a test for alkalies, which turn it brown; it is also used as a test for boracic acid.

Persian Berries.

Persian berries are the fruit of the buckthorn, and various species of *rhamnus* which grow in various parts of Southern Europe and Asia.

The nature of the colouring matter contained in Persian berries has been the subject of much research, but it is still involved in much obscurity.

It seems, however, to be established that there is a glucoside in Persian berries which crystallizes in yellow silky needles, to which various names have been assigned such as chrysorhamnin, xanthorhamnin, and rhamnin.

In wool-dyeing Persian berries find no use in the heavy woollen trade, the colour which they give to mordanted wool not being sufficiently fast to withstand milling and scouring processes. It is, however, often employed as a yellow dye for goods for ladies' wear, such as scarlets and oranges.

Sumac.

This astringent substance is of considerable importance in the dyeing of certain drabs and browns on woollen goods, as, in addition to the tannin which it contains, there is also a yellow colouring matter which has not yet been studied, but which performs an important part in the production of browns and drabs.

Its action on wool mordanted with bichrome is to produce a fine olive yellow; with a mordant of tin, a bright yellow; and with one of copperas, a dark slate. This last effect is owing to the action of the tannin in the sumac upon the salt of iron.

Sumac, as met with in commerce, is the ground-up leaves and twigs of a tree called *Rhus coriaria*, which grows in Sicily, France, Spain, and other countries. The Sicilian variety is the most esteemed. Dr. Stenhouse has proved that the tannin of sumac is the same as that contained in gall nuts, which is called gallo-tannic acid. This acid gives a blue-black, or slate colour, with copperas mordanted material. The compound so formed is the gallo-tannate of iron.

The chief use of sumac to the woollen dyer, however, is for the purpose of dyeing cotton or vegetable matter which may happen to be mixed up with wool.

1. In the form of burls, or threads, or seeds.
2. In union or mixed goods, in which there is a cotton warp with a woollen weft.

The goods, after having been dyed in the ordinary way, as for wool, are steeped in a decoction of sumac in the cold, and then in a solution of so-called nitrate of iron, or of pyrolignite of iron, if the colour is black; but for the red wood, yellow wood, and aniline colours, the goods which have been steeped in sumac decoction are transferred to a solution of oxymuriate of tin of 2 degrees or 3 degrees Twad.

A tannate of tin is probably formed in this operation, which enables the cotton to take up dyes in the same manner as wool.

There are certain red colouring matters which are extensively used in one branch of dyeing which I will now describe.

Cochineal.

Cochineal is the dried body of an insect which lives and feeds upon a cactus; the insect is called *Coccus cacti*, and it is the female which furnishes the dye. The male insect is furnished with wings, but the female is wingless, and remains stationary on the plant. The insects are brushed off the leaves with a soft brush, and dipped momentarily into boiling water to kill them; they are then dried and sent to market.

There are two principal varieties met with in commerce; —(*a*) Silver cochineal, which is coated over with a mealy substance; and (*b*) black cochineal.

I have met with silver cochineal adulterated with sulphate of barium, which at the same time gives it a mealy appearance and adds to its weight. Such a cochineal as this leaves too much ash when burnt.

The present price of cochineal is very low, ranging from 1*s.* 4*d.* to 2*s.* per lb.; this is due partly to the depressed state of the woollen trade, but also to the fact that some of the aniline dyes compete with it.

Cochineal is prepared for the use of the dyer by grinding it in a mill like a coffee-mill. The ground cochineal is thrown into the vat along with the goods.

The colouring matter of cochineal is carminic acid, which gives to wool mordanted with chloride of tin a scarlet colour, and with alum and tartar a crimson. The colour is very bright, and fairly fast and permanent.

On wool its chief use is for the production of scarlets, oranges, and crimsons, rose pinks, and such like colours—flannels and serges being the goods mostly dyed with cochineal colours.

The yellow portion of the scarlets is obtained by using flavin, which is the best for the purpose; or young fustic, which answers very fairly; and lastly, Persian berries are sometimes used, but the yellow colour obtained with them is not fast.

The mordant used in dyeing scarlets is a salt of tin along with tartar. There is a great diversity of practice among the dyers in the use of tin spirits in scarlet dyeing. Some use the ordinary double muriate or single muriate, others the muriate to which is added one or two per cent. of oxalic acid; some again use a nitrate of tin or a sulphomuriate. I do not know that any special preference should be given to any particular tin spirit, for I have seen equally good results with all of them. When the single muriate will answer, it seems to me unnecessary that the operation should be complicated by the use of a more complex mixture.

When goods are hard woven, a tin spirit which contains but little free acid does not answer well. The colour is deposited too much on the surface of the cloth, and the centre is often not dyed at all. A tin solution which contains a good deal of free acid, however, enables the colour to penetrate better into the centre of the cloth, because the coloured lake which is formed by the combination of the carminic acid with the oxide of tin is kept longer in solution by the free acid.

The penetration of the colour into the centre of the cloth may often be accomplished by entering the goods at a temperature below the boil, and heating the bath up to the boiling point very gradually.

A proportion of tartar greater than 4 per cent. of the woollen material to be dyed has the effect of yellowing the shade of scarlet, the yellowing being in proportion to the excess of tartar.

An increase of the tin mordant, the other materials remaining the same, has the effect of intensifying the shade of colour without sensibly increasing the yellow.

In dyeing scarlets and oranges with cochineal, the mordanting and dyeing are done in the same bath, kept at a boil for an hour or an hour and a half; wood cisterns being generally employed for the bath, and the boiling is done by perforated steam pipes.

Lac Dye

Is a red colouring matter, which has been manufactured and used in India for centuries. It is now extensively used in this country, along with, or in the place of, cochineal. It produces a colour on wool, which has greater body than cochineal, but not quite so much brilliance.

Lac dye is a secondary product in the manufacture of a gum resin, called lac, which is found on the surface of the small twigs of trees of the genus *Ficus*, on the banks of the Ganges, being deposited there by a small insect called *Coccus lacca*, and belonging, therefore, to the same genus as the cochineal insect.

The crude matter taken from the tree is coarsely powdered and macerated in hot water; the liquid is then evaporated to dryness; the dry residue is the lac dye, which often contains 50 per cent. of colouring matter.

The identity of the colouring matter of lac dye with that of cochineal has not been fully established, but there is a great similarity in their action on mordanted wool, the chief difference being in the tone and intensity, or depth, of colour. Lac-dyed colours are also somewhat faster and more permanent than those of cochineal.

Lac dye is imported in the form of hard cakes, which are ground to a fine powder for the use of the dyer. The dyer works up the powdered colour into a paste, with a mixture of hydrochloric acid and his tin spirit, and then adds it to the dye-bath along with the goods to be dyed. The dyeing is then performed exactly in the same manner as with cochineal.

In practice it is found to be advantageous to combine the brightness of the colour of cochineal with the solidity and permanency of lac dye. This is done by dyeing the goods first in a bath of lac dye, and then in a separate bath with cochineal, washing out from the first bath before entering it in the second.

The following are the proportions and cost of dyeing goods on the large scale by this process :—

Scarlet.

For 100 lbs. of cloth :—

		s.
Lac (mixed, varying from 1*s.* 6*d.* to 6*d.* per lb.), average 1*s.*		8·08
Cochineal, 2*s.* per lb.		6·00
Argol (110*s.* per cwt.), 1*s.* per lb.		5·
Tin spirit of 45 deg. Twaddel as stannous chloride	1¼*d.* per lb.	2·4
Flavine, at 2*s.* 6*d.* per lb.		·08
Cost of materials for woollen cloth		21·56

Ammoniacal Cochineal.

When cochineal is ground and worked up into a paste with strong ammonia, say 16 deg. of the ammonia gauge, the colouring matter becomes transformed into a new colour called carminamide. According to Schutzenberger this change may be represented thus :—

$$\underset{\text{Carminic acid.}}{C_9\,H_8\,O_5} + NH_3 = OH_2 + \underset{\text{Carminamide.}}{C_9\,H_9\,NO_4}$$

This colour does not produce red or scarlets, but is employed along with cochineal for the production of rose pinks, crimsons, and such like colours.

The mordant which works best with ammoniacal cochineal is the nitrate of tin.

The following are the proportions used on the large scale for the production of a rose pink :—

For 150 lbs. cloth :—

1½ lbs. ground cochineal, made into a paste with 1½ pts. ammonia 16 deg., and left over night.
2½ lbs. ground cochineal.
1¼ lbs. tin dissolved in 13 lbs. nitric acid.
5 lbs. argol.
Boil one hour.

Eosine.

A new dye known under the name of Eosine has recently been added to the list of red dyes, and as it is likely to be a competitor in the production of scarlets on wool, I have thought it advisable to give a short account of it here.

The word "Eosine" signifies day-dawn, implying that the colour is that of the rosy hue of morning. On silk the colour is that of the rose, but on wool it is scarlet.

In order to produce it a substance called resorcin, obtainable from a variety of sources, is treated with phthalic acid, whereby a new and fine yellow colouring matter is produced, called fluorescine, on account of its possessing the property of fluorescence in a marked degree. This new body, when treated with bromine, gives the colour in question, eosine, which is a bromine of fluorescine. Eosine also possesses fluorescent properties, which you will readily see as I pour the eosine solution into this tall cylinder of water and illuminate it with the magnesium light.

Woollen goods are dyed with eosine, using alum as a mordant in the same bath.

The goods are boiled for a few minutes with 8 per cent. of alum, and the dye in solution is then introduced at intervals until the requisite depth of shade is obtained.

The dye will bear soap washing fairly, but will not stand severe milling. It dyes readily along with aniline and other colours, and promises to be a very useful addition to our present list of dye wares.

CAXTON AND MODERN MACHINERY.

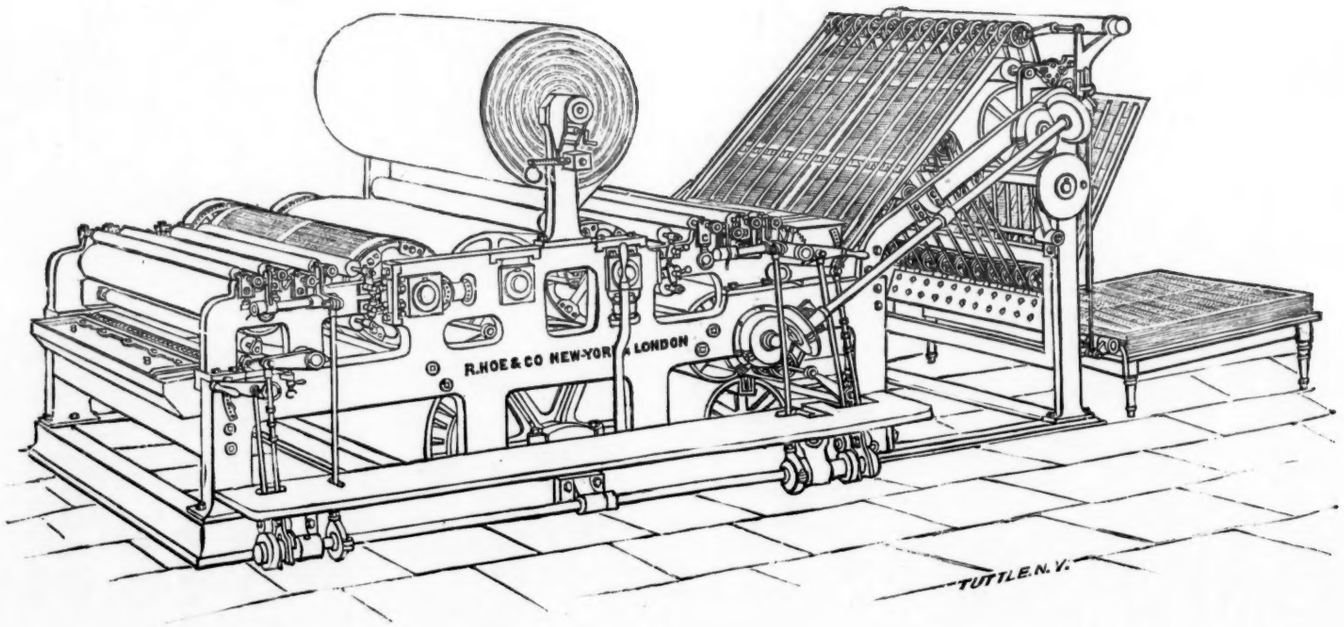
TWENTY years ago a great effort to honour the memory of the Abbey Printer of Westminster resulted in a method contrary to the idea of its advocates, but to the benefit of the trade or profession he founded. A scholarship, endowed with the money collected under the presidency of the late venerable and large-hearted Dean of St. Paul's—Dr. Milman—seems to be a much more useful form of honouring a character and name dear to all lovers of intellectual light than a monument of stone or bronze. The latter happened not to be within the possibility of the time, and the former, taken as a last resource or alternative, has kept the name of Caxton alive, and will continue to do so until the end of time.

We are, as a nation, getting weary of public statues, not because the sculptured form is unappreciated—for that will never be—but because of the manifest impropriety of filling every public place with incongruous tokens of our reverence for the men of past generations, whom we admire, but whose duplicates exist among us in many a being who can never be so honoured. Galleries of statues must soon be formed, as in classic days, and a better and more graceful immortality secured than by the ridiculous customs Prince Albert despised, but to which he has been the chief victim.

In a short time England, or rather the "English-speaking people," will have the opportunity of seeing, by means of a collection, the rise and progress of the art of printing; a collection that bids fair to be the most perfect that any future age will have the means of rivalling. The usual proprieties will be observed, such as music, dining, and preaching, and these cannot fail of being appropriate when the services of the Dean of Westminster, the genius of Mendelssohn, and the hospitality of the Printers' Corporation, are combined.

But the whole arrangements are designed to be instructive. It will be a pity if a love of pleasure, novelty, or gaping curiosity, should induce a single visitor. Caxton, if anything, is entitled to the reputation of a practical man. He assumed his labour as a printer solely from practical considerations, and his various labours show him to be the man of business who turned to account a wave of mechanical invention which happened after ages of darkness to come across Europe. That he was a London apprentice before going to Antwerp, and of the Mercers' Company, is a fact the city archives verify; as also the further fact that those meddling gentlemen who made themselves and England felt all over Europe under the designation of "Merchant Adventurers," sent Caxton out as one of their many agents to guard their interests, and to report whatever might be turned to account, whether in politics, or commerce, or art, is most true. That he had shown a faculty which made this appointment inevitable is well known. These are of archæological interest, and that is a great matter: still, if the Caxton celebration is to be instructive, the practical element—the manipulation he practised, and the subsequent improvements that have transformed the bellows press into Hoe's machine, and the solid blocks first into movable types, and the almost infinite correlative unfoldings of the master thought or suggestion, must be hoped to receive a perfect recognition.

The catalogue of Caxton's books as a printer is long, and contains a surprising variety. The specimens that will be there doubtless include all that can be recovered from the four centuries which have elapsed since the series began; and it must interest the connoisseur to compare Caxton with Mansion and


R.HOE & CO NEW-YORK LONDON
TUTTLE N.Y.

with Wynkyn de Worde, and the other printers: still, the practical man will be solicitous to ascertain the course of development in character, in type, in form of page, in style of printing, and the machinery by which the human idea became so mighty a power and so grand a blessing.

In saying this much, it must be borne in mind that the greatest part of Caxton's work has an interest for practical men quite as much as to the connoisseur or the antiquarian. The books themselves have little value, being chiefly translations from French of ancient traditions, legends, or quaint scholarly publications; but the art of the man is seen in the comparatively perfect manner in which they are executed under circumstances of extreme disadvantage.

The Earl Spencer—whose name appears on the dove-coloured tablet to the memory of Caxton in Westminster Abbey, as chairman of the Roxburgh Club,—stored reverently everything he could collect concerning early printing, and all his treasures will be at the service of the public. Of course there is nothing of Caxton's. His types have been reproduced by that master of type founding, William Caslon; these are in black letter. Besides these, the ancient matrices, &c., &c., of Baskerville and others—who followed the old Germans, and gave grace, clearness, and intelligibility to letters and books, and thereby augmented the facilities as they enhanced the taste for knowledge—add a charm to the collection that cannot fail to impress the minds of the oncoming generation, and increase their reverence for the pioneers whose labours have never been superseded, and in many instances poorly reproduced by modern artificers. Four hundred years are too much for the age of wooden presses, and it is more than doubtful whether the admirable picture by Maclise of Caxton at work in presence of his royal patrons, which is now reproduced in a popular form, contains a single article resembling the actual contents of the old printing offices. The press is the wooden one familiar to all in the last generation, and the other parts do not carry back 300 years. But too much praise cannot be given to the labourers who have exercised skill in selection and arrangement which, when the whole is open to public view, will most surely be expressed.

Lovers of music, who are familiar with the old square-shaped notes resembling a gas meter handle, and who remember in their young days the pewter-plates from which alone modern music was produced, will see the specimens gathered here; and then the rich array of founts of music type, since Messrs Parker brought out the printed folio, and Knight and Novello gave stimulus to musical taste by the adoption of the new invention of mechanical art, down to the wonders of modern lithography in that line, and the workings in brass; these will be a rich feast for the eyes of those who love practical mechanics applied to the highest service of man.

Of cynics the public will doubtless hear enough. Every cause has a weak side from the enthusiasm or pedantry sure to be alleged, but it is to enthusiasts and pedants the world owes a deeper debt than ever it will be honest enough to discharge. The occasion of honouring Caxton is taken advantage of for far higher purposes, namely, to diffuse and extend knowledge concerning the growth and condition of practical mechanics, in reference to the incalculably useful art of printing.

This brief notice of *what was* would not be complete if *what is* were omitted. Exhibition after Exhibition have popularised the progress of improvement in printing machinery; but no Exhibition has yet contained the latest of these changes. All newspapers of large circulation have been compelled to adopt it, notwithstanding the wonderful creation known as the "Walter," which is now at the South Kensington Museum, and had previously been well known to many thousands of visitors at the Industrial. In that machine a first requisite depended on human labour; the paper had to be placed by hand in ordinary sheets; but this dispenses with such instrumentality, and feeds itself. Our columns in 1876 contained a description of paper-making, wherein we showed that for paper-hangings the paper could be sent in upon rolls in a continuous length of a mile; and, in fact, the paper-maker did not care if he made it fifty miles. This machine requires reels containing from four to five miles, and all the hand-feeding demanded is to place the reel, as seen in the illustration, on the top, and lead the end into square contact with the printing press by means of a continuous web. Then it will go on, cut off the copies by a kind of wave deckle, fold it in four, all printed, and fit for sale, at the rate of 12,000 to 15,000 an hour, keeping account by a "tell-tale" of the number struck off. It is impossible for any one to say what may not be invented in the future; but it is right to affirm that there is not in the whole range of machinery anything yet produced to rival Hoe's latest machine for printing.

But unless previous inventions had been made this could never have been thought of: for instance, printing from types, although superseded by stereotyping by the use of paper and printing from the flat "forme," to the unending method, had not been superseded by cylinder working. Let us explain this foundation work. Every one who, going about a city, or in the country, visits a printing office, is acquainted with the process of collecting the types, adjusting the lines, arranging the pages, and fixing all into an iron frame called "a chase." These cannot be dispensed with, for they provide the basis of modern stereotyping. Instead of taking the form in plaster of Paris, and pouring lead into the mould, the cast is made of half-a-dozen thicknesses of pasted paper pressed successively into the interstices of the type down to the "shoulder"—the top of the "shank"—by a powerful rolling press. From thence the type and its covering passes to a screw press that has a heated bottom plate, where pressure is again applied, the moisture extracted, and the whole made into a solid mass. When thoroughly dry the covering is pulled off, and a perfect counterpart of the type is before you. Being flexible, it is then placed with its face upwards on the inside of a semi-circular mould made of cast-iron, and its edges are fastened down by iron bands or clips of the exact thickness of the cast. On these a hinged counterpart of the mould is let down and secured by four clamps. The machinery for this mould is so constructed that it can be swung on end; and that being done, it is filled up to the mouth with molten stereotype mixture which cools in two minutes, when the mould is opened, the plate removed, and the paper matrix peeled off, scarcely the worse for its hot usage, for it can be used again. This stereotype plate is then placed on a cylinder of the same diameter as the type cylinder in the printing machine; its edges are trimmed, and by a revolving cutter the head is cut off as excess metal. The cast now looks to be a strong quarter-cylinder of stereo-metal: four of them, forming the pages of a newspaper, are placed on one cylinder and the other four for the other side are placed on another cylinder.

Over the centre of the machine is placed a coil of paper ready damped. The end is dropped between the first pair of types and the impression cylinders, which have two blankets. The cylinders are made of the same size surface as the sheet to be produced, and every revolution produces a copy printed on one side. The operation is repeated by the sheet being caught up and passed over other reels, and printed on the other side, but in the meantime it passes round the large wheel which is covered with blankets that absorb the surplus ink, and prevent the smudging that must follow from too hasty work. This addition enables the whole work to go on for 200,000 impressions without change or imperfection: and when it is too foul, all that is necessary is to wind the old blanket on to one roller, and pay in a fresh one.

The management of inking is so well done in Hoe's machine that no improvement is attempted by rivals or inventors. The object is to give the entire type surface a perfectly equable proportion of ink black enough for the work, but not roughly done. It is thus effected. The ink is placed in a receptacle as in the paper-hanging factory, in which a roller revolves and grinds the ink up to the surface, where it is taken off by a lifting roller, and deposited on the distributing cylinder running at a similar progress to the other machine previously described.

The inking rollers are clothed with the ordinary composition of glue and treacle, which superseded the old balls fifty and more years ago, and receives the ink in order to work it down to the utmost fineness by their combined revolutions against each other, and are so arranged as to impinge upon the type cylinders at the same time with the utmost nicety.

When the work of printing is completed, the paper is conducted by a little guide on to another set of apparatus which cuts each sheet from the coil, and, if necessary, folds it also. A sight of it in operation is now obtainable in most of our large towns, and that is better than the most accurate description that could be supplied.

These machines are the latest, as those of Caxton the earliest, and the contrast they exhibit is the best evidence of the progress made in the interval of time.

SOLID STEEL CASTINGS.

ONE of the most interesting meetings of the Mechanical and Scientific Societies of this season took place a few weeks ago at the rooms of the Institution of Civil Engineers in Great George Street, which had been lent to that prosperous Society, the Iron and Steel Institute, for the purpose of hearing the inaugural address of the new President, Mr. C. W. Siemens, and to

receive a paper from Mons. F. Gautier of Paris, on the above subject, which we now lay before our readers :—

"When steel is cast in an iron ingot mould, or a mould of any kind, usually the metal after cooling is not entirely sound. Cavities of a more or less rounded shape are seen inside, apparently caused by a gas escaping from the mass. Mr. Henry Bessemer, the first among the metallurgists, has demonstrated that these blow-holes were filled with oxide of carbon, and this view has since been entirely confirmed. Refining produces oxide of iron, $Fe^3 O^4$, which re-acts on the carbon according to the formula :—

$$Fe^3 O^4 + C = 3\,Fe\,O + CO.$$

The protoxide of iron passes into the slag, and the oxide of carbon remains in dissolution within the metal. But the solubility of the oxide of carbon diminishes rapidly during the cooling period, and some gas bubbles remain imprisoned in the solidified mass. When these blow-holes are altogether inside, and do not burst through the crust, they remain silvery white : it is a simple solution of continuity, and to get rid of them it is sufficient to weld the metallic parts by reheating and the use of a hammer or rolls. What becomes of the carbonic oxide? Is it re-incorporated with the metal? This has not been determined yet. But the fact is, that when rolled steel bars, drawn from honeycombed ingots, are broken, no trace is found of this kind of defect. When the blow-holes communicate with the outside, and the sides of the ingots are pierced with small holes, well known to the steel manufacturers, the colour is no longer a silvery white ; they assume more or less the colours of the rainbow, and even become black. This takes place because the carbonic oxide of the blow-holes is transformed by the contact with the air into carbonic acid, and oxidation of the metal occurs.

$$3\,CO^2 + {}_2\,Fe = Fe^2\,O^3 + 3\,CO$$
$$\text{or, } 4\,CO^2 + {}_3\,Fe = Fe^3\,O^4 + 4\,CO$$

according to the temperature when the reaction takes place. We know, from Mr. I. L. Bell's works, that the oxidation of iron by carbonic acid begins at about 300 degrees C. (570 F.), and is very strong at high temperature. Hammering and rolling do not entirely eliminate these blow-holes, as a perfect welding of the metallic particles is prevented by the presence of oxide of iron. There remains some black streaks which sometimes penetrate to a depth of $\frac{1}{10}$ in. (2 millim.). In order to correct these surface defects the welding must be done by allowing the piece to undergo heating at as high a temperature as possible ; the steel is then covered with sand and hammered vigorously. The oxide of iron which prevented welding is combined with silica, and forms a silicate which pressure easily expels. This is a general practice in the manufacture of fine steels. It will be seen that it is an easy matter to remove blow-holes when the steel has to undergo mechanical elaboration : but it is not so with castings, and it is very important to prevent the formation of these blow-holes when sound pieces are wanted, and pieces the resistance of which can be relied upon. All steels have not the same tendency to produce blow-holes while solidifying. Generally, the more a steel is carbonised, the better it will flow while casting, and fewer blow-holes will form. On the contrary, the more a steel is decarbonised the less fluid it will be, and more blow-holes will form. It is probable that hard steels keep better their oxide of carbon in dissolution, or else it escapes more freely on account of the greater fluidity of the metal. This property of highly-carburised steels has led to the casting of thin pieces without blow-holes, or almost without blow-holes. A very hard steel, with about 1·5 of carbon, is cast in thoroughly dry moulds. The castings thus obtained are left for several days in an oxidising atmosphere, or even in contact with a bed of oxide of iron or zinc, as in the manufacture of malleable iron. Very strong products are obtained in this manner, but they must be very thin, and even then they are far from being without blow-holes. As is the case with malleable iron, thick pieces are out of the question, as decarburising goes little by little, from molecule to molecule, and through a solid body. If the pieces were too thick the outside would become oxidised before there was a thorough decarburising of the mass. This very interesting process is carried on with success at Sheffield. We have to speak now of the German manufacture of steel without blow-holes. Every one will remember those splendid ingots, clean-fractured, growing in weight at each successive exhibition, first beginning with two tons, and finally reaching forty-five. The Krupp ingots, the cast wheels and bells of Bochum, certainly astonished the metallurgical world for some time. The process of manufacture was kept a most profound secret, and has not yet been published. More than six years ago, the Terre-noire Steel works found out by reasoning rather than by practice, the process of the German works, and the improvements they have made have radically transformed the result. It seems well proven now that the German products, without blow-holes, are obtained by an addition of a very siliceous pig just before casting ; and thus they are found to be highly carburised, and the chemical analysis shows a rather considerable portion of silicon. To find an explanation of the result we must go back to the theory of the Bessemer process. It is well known that the combustion of the silicon takes place during the first part of the operation ; there is no flame, or rather there is a series of brilliant sparks ; the yellow sodium band, characteristic of all flames, is not seen ; no oxide of carbon is formed while there remains any silicon to be oxidised ; the silicon decomposes the oxide of carbon, or, which is the same, prevents it from forming ; therefore, if blow-holes are filled with oxide of carbon, they will be made to disappear by the addition of silicon

$$Si + 3CO = SiO^3 + 3C.$$

The carbon is deposited and dissolved in the steel, and silica is formed. Experience shows that steels treated in this manner are generally without blow-holes. In order to prove this theory, the following experiment can be made. A bath of siliceous pig is formed in a Siemens-Martin furnace, and refined by successive additions of iron or steel. Tests are taken at short intervals. At first these tests are quite sound, but they become full of blow-holes. If a chemical analysis is made, it is found that the first honey-combed test contains no silicon, while the succeeding ones contain some. If the products obtained in this manner are without blow-holes, the quality is rather inferior, in spite of the long annealing they usually undergo after casting. We will analyse the several causes of this inferiority. (1) These steels are very highly carburised : the pig being generally poor in silicon, the operator is led to charge a rather large quantity, so as to be sure that it will act effectually. (2) The silica produced by the chemical re-action that destroys the blow-holes is, indeed, generally combined with oxide of iron in the bath ; but the slag is slightly fluid, and remains in the steel, which is thus made pasty. It lessens its strength ; it may even make it crumble when trying to work it hot. (3) There remains in the final product an excess of silicon, which, in addition to the excess of carbon, tends to lower its quality. This influence of silicon on pigs and steels has been anything but clear for a long time, and it may be said that even now it is not perfectly known. I think it useful, at any rate, to speak here of the curious experiments made by the late Wenzel Mrazek, of the School of Mines at Przibram, Bohemia. Silicium always had the very worst reputation in metallurgy. Karsten, whom the Germans modestly call the immortal, was the first to assert that silicon gave to iron a special red-short quality—*faul-brüchig*—with a peculiar fracture, an earthy fracture. This opinion was allowed to spread without any disputing until lately, when Mrazek showed that the action attributed to silicon should be ascribed to the silica found in the silicate mixed with the iron ; for if metallic silicon of good quality is added to a certain quantity of iron, the original qualities of the metal are in no point changed. This view is much more logical from a chemical standpoint, for it is well known that in the refining period silicon disappears first of all ; it would be necessary to suppose that after refining is done the silicon is again reduced in spite of the oxidising influences, passes back into the metal, and makes it red-short. It is, therefore, impossible to believe there is any free silicon in the iron in a notable quantity ; but the material found is silicate, such as that of steel without blow-holes of which we have just spoken. But if silicon is harmless in a soft metal, it is far from being so in a product containing carbon. In a preceding communication, I spoke of the incompatibility of carbon and phosphorus in steel, and of the necessity of suppressing carbon when using phosphorus. Mrazek's experiments prove that there is also incompatibility between carbon and silicon in steel. The simultaneous presence of carbon and silicon causes brittleness, hot or cold, while a cast metal, containing slight traces of carbon only, will bear up to 7 per cent. of silicon, and still roll well at red or white heat, and will even weld perfectly well. Therefore, if a quantity of silicon is wanted in a cast steel, and there must be some to ensure perfect soundness, it will be necessary, in order to obtain a good product, not to entirely suppress the carbon, but at least to lessen the quantity considerably. At the Terre-noire Steel Works, the manufacture of steel without blow-holes has been perfected by using a silicide of manganese and iron, which gives to the product remarkable qualities. The silicon prevents blow-holes by decomposing the oxide of carbon, which is in dissolution, and tends to escape during solidification. The manganese reduces the oxide of iron, and prevents a further production of gases by the reaction of the oxide on the carbon. We have seen above that in the decomposition of oxide of carbon by silicon, silica was produced, and afterwards a silicate of iron, which remained interposed within the steel. The manganese allows the formation of a silicate of iron and manganese, which is much more fusible and passes into the slag. For this reason, the metal is not altered by a foreign

body, and this is a capital point. In order to show plainly the complete structural difference between steels without blow-holes obtained with silicon alone and those obtained with an alloy of silicon and manganese, M. Pourcel operates in the following manner. In a porcelain tube he places two receptacles, one holding steel by silicon alone, and the other steel by an alloy of silicon and manganese. A current of chloride is passed until all the iron is removed in a state of chloride. It is seen then that in the first receptacle, there remains a network of silicate of iron preserving the original form of the pieces, while the steel by alloy leaves no residuum. We already know that an excess of manganese remaining in a steel improved the quality of it; we learn from Mrazek's experiments that a slightly carburised steel containing free silicon and manganese at the same time, can be excellent. A steel bearing

Silicon	1·50
Manganese	0·76
Carbon	0·18

is very strong and rolls perfectly. It is therefore useless to be much concerned about the excess of manganese or silicon that may remain in the steel cast in this manner. More than 500 charges of steel without blow-holes were analysed and tested at Terre-noire, and below are the results obtained in tensile strength with cast metal of three different qualities :—

Charge in Tons (2,240 lb.) per Square Inch. Elongation Measured on a 4-in. Test Bar.

		Raw metal, coming out of the mould. Tons per sq. in.			Metal, re-heated and cooled slowly. Tons per sq. in.		
	NO.	Elastic limit.	Breaking load.	Elongation per cent.	Elastic limit.	Breaking load.	Elongation per cent.
Hard steel for Projectiles	948	21·0	40·4	1·7	24·8	52·0	7·25
	966	19·8	39·0	2·0	22·4	51·0	8·50
	1355	22·0	34·0	2·0	23·6	51·5	8·00
	1502	24·3	33·2	1·0	27·3	57·1	7·40
	1737	21·2	35·0	1·7	24·2	59·0	7·00
	1872	22·0	38·9	1·5	25·6	56·0	3·40
Strong soft steel	1545	23·2	40·5	2·0	24·2	52·0	12·2
	1558	21·7	43·7	3·3	25·3	51·0	14·0
	1563	20·6	41·8	2·5	24·3	51·9	17·5
Very soft steel	2078	10·3	32·7	12·5	16·0	34·5	28·5
	2081	12·7	34·4	12·4	18·8	35·6	25·6
	2149	13·3	33·2	12·5	18·0	35·4	24·3

This metal is in no respect similar to the steel without blow-hole castings made until now; it can be hammered, and rolls without flaws; it resists hard blows, and when soft will stand considerable bending before breaking; in a word, in the form of a moulded piece it possesses the same properties as a rolled and hammered metal. This brings us to speak of a very remarkable paper by M. Chernoff, an engineer at the Aboukoff Steel Works, St. Petersburg. This paper is on the structure of steel. A steel ingot is a body coming more or less rapidly from a liquid to a solid state, and preserving a more or less crystalline texture. There is one general rule, and that is, that all metals possessing a crystalline texture are brittle, as for instance antimony, bismuth, zinc in ingots; while a confused and irregular texture corresponds to the greatest resistance. Steel is not an exception to this rule, and if a fracture is crystalline, the piece is very brittle. Fortunately, this defect can be modified in several ways. (1) By simple re-heating to cherry red, when an ingot with coarse fracture, and completely lacking the requisite strength, will suddenly be transformed after ordinary cooling into a fine grained and strong product. (2) By hammering at a sufficiently high temperature, cast steel loses its crystalline structure, provided this hammering is continued, while cooling takes place, down to a certain point varying with the different steels, and beyond which the metal preserves its whole power of resistance. If hammering was left off at a high temperature, and the metal abandoned to itself, the crystalline structure would re-appear, and with it the lack of strength. (3) The rapid cooling of a cast metal also destroys the crystalline state; this was observed in wrought iron armour plates. Steel, then, seems to behave like an exceedingly concentrated dissolution of a salt easily crystallisable, the crystallisation of which is prevented by certain precautions only. For M. Chernoff, as well as for us, unwrought cast steel is neither softer nor weaker than a steel of the same grain forged at a suitable temperature. Of course, we are speaking of steels without any defects, cracks, or blow-holes, or else a comparison would no longer be possible. M. Chernoff took a coarse-grained cast steel ingot, and had it cut lengthwise into four parts. One of the quarters was transformed directly, on a lathe, into a test bar. The second was heated to a bright red, forged under a steam hammer, the forging being stopped whilst the piece was yet rather hot. The third piece was heated up to the point at which the hammering of the preceding piece had been left off, and then was allowed to cool freely. The fracture showed a very fine grain, very similar to that of the forged piece. These two quarters were also transformed into test-bars. The results of the traction tests were as follows :—

In tons per square inch.	Breaking load.	Elongation.
No. 1. Untouched ingot	38·5	2·3
No. 2. Forged ingot	45·5	5·3
No. 3. Ingot re-heated and cooled in air	43·0	16·6

We believe, like M. Chernoff, that it is possible to have a steel cast directly just as strong as if it was hammered, provided that the metal be regularly without blow-holes, and crystallisation done away with. On M. Chernoff's part, this is a theoretical intuition, resulting from an enlightened study of a material. With us it is more than an opinion, for we bring a practical realisation. The very interesting fact that cast metal may have a higher density than forged and rolled metal, has not yet been pointed out, yet at Terre-noire it was ascertained that this density varied from 7·8 to 7·9, while that of rolled steel never went beyond 7·81. It would seem, from this experiment, that the rolling process causes not only a different arrangement of the molecules in reference to one another, but also a slight increase of volume. The question is now, in presence of these two facts—(1) That a cast steel may be more dense than a hammered one, (2) That its strength may also be superior. What can be the use of the compression of liquid steel? Compression applied to steel was tried simultaneously twelve years ago at Terre-noire and at Manchester by Sir Joseph Whitworth. The first results obtained on the Continent were such as to cause the process to be soon abandoned and forgotten. Two years ago new experiments were made in many places; but it seems well proved now that there is nothing to be done in this direction. At Manchester, on the other hand, it is said that very interesting results were obtained; the compressed metal, it is said, bears 43 tons per square inch, with 32 per cent. elongation on a 2-in. length—which corresponds to 20—22 per cent. on 4-in. How are we to explain this difference? Undoubtedly the *modus operandi* is not the same, for in France and in Prussia no such result was ever reached. It is to be regretted that, two years ago, during the visit paid at the Manchester works, the members of the Iron and Steel Institute were not enabled to get any idea of the efficiency of the process otherwise than by a walk in a deserted workshop; the explanation of this great difference of results between two neighbouring countries applying the same process could then have been found. Compression cannot seriously modify density, for when the cast metal is perfectly sound it possesses a density higher than that of forged metal. But it might very well happen that, at the time of solidification, crystallisation is stopped by a powerful compression, and the metal acquires properties, similar to those of forged product. But at any rate, if compression can, in skilful hands, give good results, these results can be obtained in another way, a simpler one, and, we believe, a surer one; I mean the process I have just explained in the name of the Terre-noire Company. The first practical application of the metal without blow-holes now manufactured at Terre-noire is due to the genius and perseverance of M. Euverte, the skilful director. The use of hollow projectiles bursting inside the ship, after having penetrated through the armour, has, with an equal power of penetration, great advantages on solid projectiles. They burst into pieces both numerous and dangerous; they shake, dislocate, and break the inside lining to a great extent, and the resulting leakages cannot be stopped up. Chilled cast iron balls being low priced compared with forged steel ones—six or eight times cheaper—and the manufacture of them much more rapid, a great economy could be realised, from a military stand-point, by using them. Gradatz, Finspong, Terre-noire, Châtillon, Piombino, and Palliser, furnished samples, but without any good results; the projectiles split and break in normal firing when the plates they strike against are rather thick. In oblique firing, even against comparatively thin walls the chilled iron shot break at 20 deg., and at 30 deg. they are pulverised. This deformation of the projectile diminishes its penetrating power, since the

actuating force is spent in sterile efforts to break, and, according to Captain Noble's formula :

$$\frac{WV^2}{2g} = 2\,NRKB^2$$

It is this actuating force that measures the penetrating power with equal diameters. Furthermore, the cracks, which at first sight do not seem very hurtful, prevent a sufficient tension of the gas during explosion of the powder, and poor effects are obtained. In spite of the seeming boldness in substituting cast for forged steel, in spite of the little faith of the ordnance men themselves, at this moment the steel works at Terre-noire manufacture regularly 9½ in. projectiles capable of penetrating at an angle of 30 deg. plates 8 in. thick with the relatively slow speed of 1,400 ft. per second. The projectiles never break, sometimes the point is slighty bent. This is, I venture to say, the severest test a cast metal can be subjected to, for in the trials of which I speak this cast metal showed itself superior to forged steel both in strength and regularity. After this undisputed success, of which you undoubtedly have heard, for it is now nearly a year old, M. Euverte asked himself the question whether the efforts to which the metal is subjected in a cannon are not much weaker than when a projectile pierces an armour plate. It is true there is a difference, for in one case the metal is compressed and in the other drawn. It is not known yet whether it will be possible to begin immediately the manufacture of cannons in one piece, as was formerly done in cast iron cannons for the navy and the defence of towns. But there is one idea which presented itself naturally, and is being studied even now—it is nothing less than the replacing the cast iron body by a cast steel one in coiled guns. Thus, a metal hardly able to stand an effort equal to 10 tons, will be replaced by another requiring 33 tons at least to break it, supposing, for security sake, that the softest metal was used. Will the application of this new metal stop here? Decidedly not. You know that in the latest trials at Spezzia, the 100-ton gun was not able to force a projectile through a forged steel armour plate. It is but just to say that the plate was pulverised ; but for some ordnance men this result is very interesting ; they consider a ship as sufficiently protected when the outside plating is not pierced through by the projectile ; they would even prefer to use plates thick enough to absorb the actuating force of the ball while being pulverised, even if they should leave a portion of the ship bare, for it seems very improbable that the same portion of the ship could be struck twice, considering the distances at which naval fights will take place with the new artillery. If the new cast metal is used for this purpose, the softest qualities only must be used ; but so far every circumstance points to a great result to be reached with enormous economy. As to the different industrial applications, they naturally present themselves to every mind, and we might even say they will push themselves forward, bearing with them these two great advantages—solidity and economy."

MR. DIXON'S PLAN FOR REMOVING THE OBELISK FROM ALEXANDRIA TO THE THAMES.

ALTHOUGH almost every journal has had something to say concerning the romantic project for bringing the monolith, commonly described as Cleopatra's needle, over the seas, and setting it up on the banks of the Thames, there is an opportunity for noticing that aspect of the subject which may be spoken of as mechanical. Set up more than three thousand years ago, by Queen Nitocris, in honour of her father-in-law Thothmosis I., at Thebes, it was brought by Cleopatra to Alexandria. Egypt has had many great historic women, but among them these two occupy most prominent positions. Nitocris was the last of the race of the Memphite sovereigns and a strong minded ambitious creature. Handsome among women, brave among men, she governed the kingdom for her husband with great splendour, and being a sovereign in her own right, her likeness is on the face of the obelisk in man's clothes. Cleopatra, another wonder in history, brought them from Thebes, and placed them in front of the temple she built in affection for Anthony.

As the rude methods of effecting what we term mechanical operations then prevalent has given way to the countless devices of modern engineering, so this strange stone, that probably travelled in a sledge, is, we hope, to reach this new land by methods as strange and complicated as ever contrast could have imagined.

When an obelisk of 90 feet long, or a statue 50 feet high, was to be placed upright, a groove, or notch, was first cut in the pedestal on which it was to stand, so that, while it was being raised, one edge of the lower end might turn in that groove as on a hinge. The obelisk, or statue, was then brought by means of rollers till its lower end rested over this groove, and then its head was lifted up probably by means of a mound of earth, which was raised higher and higher, till the stone which leaned on it was set up on one end. Egyptians do not appear to have known the screw, the pulley, or the wheel and axle.

The companion obelisk to this is set up in Rome, but how it was conveyed across the Mediterranean Sea there is no tradition. We can only suppose it to have been effected by means of a huge raft. Such a journey must have been perilous enough, but we should despair if no better means could be devised for traversing, not only the Mediterranean, but the Bay of Biscay, the Atlantic Ocean, and the English Channel, not forgetting the troublesome currents and sands appertaining to the Thames. It weighs 220 tons, and without a pedestal, is 60 feet long by 8 feet square. Its former proprietors left it a few feet above high water mark, and that is about as convenient a place as could have been thought of. In 1815, the Egyptian government made a present of it to our government, but difficulties of a graver character than even the mechanical occupied public attention, and it lay unheeded on another man's land. There has been some difficulty raised by the present landholder about giving up what has prevented the profitable occupation of his property, but the Khedive and his ministers have overruled all that, on the ground that a national gift cannot be interfered with by a private person.

Mr. Dixon, C.E., of Laurence Pountney Lane, London, has contrived a ship, which, he believes, cannot fail, and which every one must hope, will succeed. He intends to build around the obelisk upon the shore a cylindrical iron-case or ship, and then to roll the whole into the sea. He then will proceed to take her into dry-dock, and make several additions, and provide ballast, on the completion of which he intends to have her towed to England. The iron vessel is now being made at the Thames Iron Works, and when the pieces are all ready, Mr. Waynner Dixon intends going to Alexandria to superintend the operations. It is necessary the ship's length be more than 90 feet and 15 in diameter, and made of plates ⅜ths thick. There are to be eight bulk-heads and the compartments watertight ; this will make the entire weight 75 tons, or a total of more than 300. For the removal, enormous jacks are being prepared in England, and there will be tremendous labour in getting the whole afloat. Its displacement is only of the depth of 9 feet, but the shore there being very gradual, it is not possible to get her out to sea without a rolling of 400 yards.

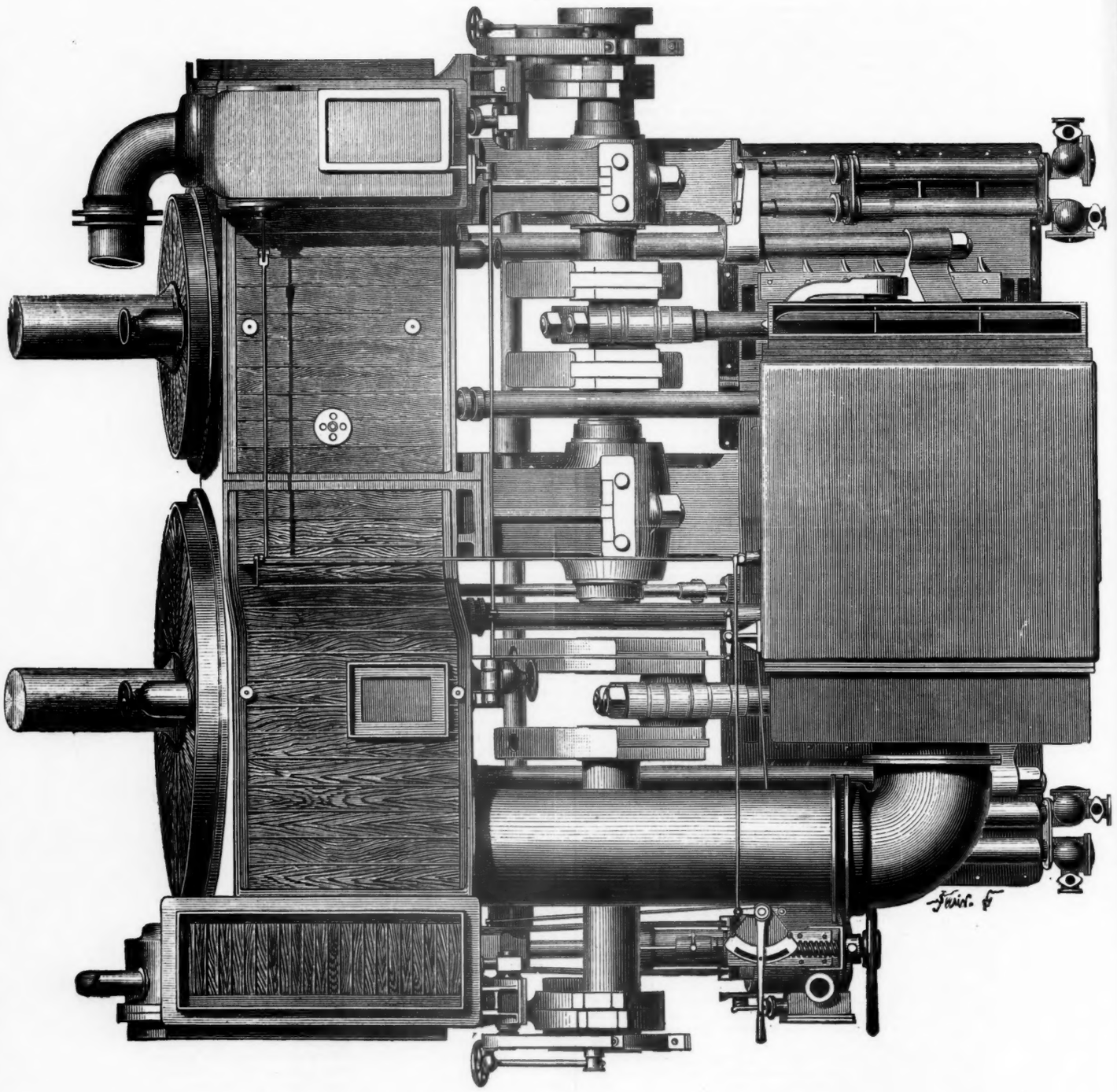
When afloat and in dock, it will be fitted with bilge keels, rudder, and steering gear, be cuttter-rigged, with one mast and two sails, and a deck-house for the gentleman who will take the charge of convoy. It is thought best to provide this double protection, for, although tugged by a powerful steamer, one of the two might come to grief either by the weather, or the breaking away of the wire-cables connecting them. A crew of five will be "on board" for making sail, pumping, lighting and signalling.

The public is doubtless aware that the old arrangement whereby Major Alexander agreed to carry out this undertaking has been put aside, and the arrangement now stands for Mr. Erasmus Wilson, the distinguished surgeon, to undertake the entire charge ; in the event of success, at a cost not exceeding £10,000 ; and if failure ensues, Mr. Dixon will lose all claim either for service or compensation. That it may be a success must be the hope of every one, whether engaged in politics, municipal life, mechanical science, or literature. That it will be seems to be the opinion of eminent engineers.

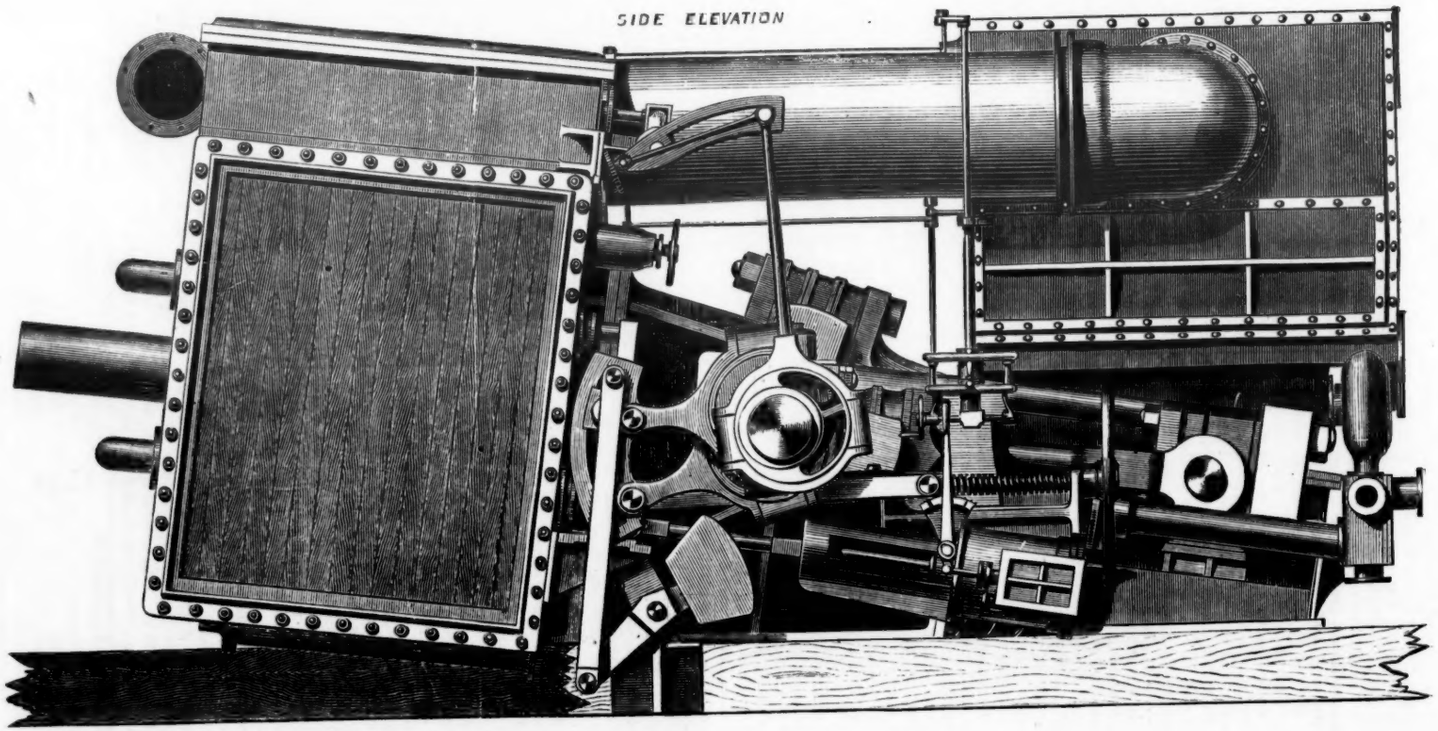
H. M. S. TOURMALINE—COMPOUND ENGINES.

THE misfortunes of the Tourmaline have brought this advantage : the manufacturers are now allowed to make public the design and construction of all Her Majesty's ships, and the public is thereby better able to ascertain the facts concerning the causes of disaster ; and journalists, technical or otherwise, are readily led to sounder conclusions than could be obtained before. The *Times* wrote, in an exaggerated style, on the 7th of April, about these causes, and, as somebody must be blamed —we suppose, on the principle that every debtor has a creditor —the manufacturers had scant justice at its hands ; indeed, they complain of injustice in terms which the newspaper would not print, "That the writer was not an engineer—that he did not

PLAN



SIDE ELEVATION



know what he was talking about—that his letter evidenced a disposition seriously to injure the character and reputation of the engine staff—that he made, on board one of Her Majesty's ships, charges and insinuations of the gravest nature, anonymously, to the serious damage or discredit of the service in which he was employed." The *Engineer* did not imitate the violent language of the great journal, but complained of many matters to the disparagement of the contractors, but also regretting that the Government should put every available obstacle in the way of any journal pursuing fair inquiry into its proceedings.

The consequence of these complaints has been the issue of a privilege to publish, of which our esteemed contemporary, the *Engineer*, instantly availed itself, and which, by its kind permission, we now reproduce in two engravings, illustrating the compounding engines of that vessel. These explain themselves to those who know what such things are; the scientific readers may, however, be glad to have a compendium of the general arrangements as supplied by Messrs. Hawthorn in the correspondence referred to. But previously we will hear her story.

The Tourmaline is a composite screw corvette, 1864 tons burthen, 350 horse-power indicated, and was commissioned in 1864, fitted with compound engines. She was ordered to the West Coast of Africa. On her trial trip off Sheerness, some trouble occurred with a hot bearing; this was patched up with white metal, and the vessel departed, but only to Deal, for the weather became bad, and the repair heated. When the calmer time returned, she went on her way, and after a short period the tank in connection with the hot well gave way and the boilers had to be filled from the sea, which water caused them to "prime," and that caused the engines to stop. This repaired, the trunk on the after cylinder gave way. The spark-trunk was placed on the cylinder while the vessel was rolling in the Bay of Biscay. The engines were again started; no vacuum could be obtained, and on further examination, several hundred tubes had started, causing five days' repairs, &c., &c.

Messrs. Hawthorn contend that all this was the result of the priming of the boiler; and their allegation is a reasonable one. Other disasters followed, causing much confusion, which was increased by the chief engineer having committed suicide. We have no business to enter upon the controversial matter, and certainly no desire, and therefore we will allow the makers to tell their own tale describing the arrangements of the ship. That is of permanent interest; the other is not.

"The Tourmaline is one of four corvettes, all similar; the Diamond and Sapphire have now been working two years very satisfactorily and the machinery is identical with that of the Tourmaline and the Garnet at present being fitted at Chatham. She had her official trial on the 22nd June, 1876, the machinery having previously had trial at moorings, and the preliminary trial at full power on the 8th June, before going on the official trial. On each and all these occasions the engines worked well and cool, with a steam pressure from 55 lb. to 60 lb. per square inch; vacuum, 26 in. to 26½ in., the revolutions varying from 75 to 100 per minute. On the official trial for speed and power the engines worked very satisfactorily, averaging over the six measured mile runs 94 revolutions per minute, and 2,141 indicated horse-power; the mean pressure in the high-pressure cylinder, 25·8 lb. per square inch = 1,036 indicated horse-power, and in the low-pressure cylinder, 11·04 lb. per square inch = 1,105 indicated horse-power. The mean speed of trip, 13·347 knots per hour. The duration of this trial was 3½ hours, and the time at full speed, without stopping, running the measured miles, 1 hour 4 min. During this trial there were no hot bearings, the ordinary water service to bearings only was kept running a little to keep them in order. The boilers, of which there are six—made to designs supplied by the Admiralty, 10 ft. diameter and 9 ft. long, with two furnaces 3 ft. 3 in. in each—primed a little on first starting, but with ordinary care were kept steadily working during the trials. On the 10th November, 1876, the Commission trial took place, and the engines were run continuously at full power for six hours. This trial was conducted by the Steam Reserve officers from Chatham Dockyard, the contractors' agent attending merely as a representative. On this occasion, we understand, the boilers primed a little, but not seriously, the engines worked well, one bearing only heated slightly, and a mean indicated horse-power of 1,972 was maintained during the run of six hours. Such is the history of the steam trials to which the machinery of the Tourmaline was subjected before starting on her commission. In addition to these trials under steam, we may mention that each part of the engines—that is, the cylinders, their steam-jackets, condenser, &c., and boilers, hot well, tanks, and pumps—was subjected to a hydraulic test, before leaving our works, to double the working pressure, and again to a similar test before steaming at moorings at Middlesbrough; and each part opened out and thoroughly examined after each of the trials, and *very specially* by the Admiralty officers, before being taken over after the official trial at Sheerness, and reported satisfactory. The construction of the engines at our works, the erection on board at Middlesbrough, the inspections and trials of all the parts were under the personal superintendence of Mr. Pitt—the late chief engineer—and certificates of efficiency were given by him to the Admiralty. We, as the contractors, satisfactorily discharged our engagements, and the machinery of Her Majesty's ship Tourmaline passed from our hands into the charge of the officers of Her Majesty's navy in a satisfactory and approved condition. We would remark that here our personal supervision and knowledge of the working of the machinery ends. It is from this point entirely in the hands of the chief engineer. The distance from Sheerness to Deal is not more than fifty miles, but from the report it seems that, during the run, a bearing had heated so badly as to necessitate stoppage, and the feed tank burst; the heating of the bearing was excusable, but why the tank should burst we do not understand, except on the hypothesis, which we venture to submit as the cause of all the troubles which occurred during the entire voyage, viz., that the boilers primed badly owing to being filled with the muddy water of the Medway, and that proper care and judgment was not exercised in the management of the boilers and general working of the engines when this occurred. The feed tank is placed about 6 feet below the water line, is open to the hot well, to the engine-room by an air pipe carried above water-line, and to the air pump discharge which is immediately under the water-line—and only on the presumption that the engines had been allowed to become choked with water, and the water forced with great velocity and pressure through the condenser tubes, air pump, and hot well, can the bursting of the feed tank or supplementary hot well, and the displacement of condenser tubes afterwards discovered, be accounted for, for it must be observed that each of these had previously been tested to double the working pressure on two occasions under the inspection and to the satisfaction of Mr. Pitt, besides working on the several trials and run from Middlesbrough. The bursting of the after piston trunk casing, the unsatisfactory working of low-pressure piston, and breakage of the trunk guide, all indicate the same cause—extreme and undue strain on all the parts, caused by want of judgment in the management of the engines while the boilers were priming. To our mind it is clear that the low-pressure cylinders must whilst working have been filled stroke after stroke with water, the whole of which would have to be forced through the condenser tubes (the condenser surface being inside the tubes) at a velocity many times greater than that of the piston. The mischief caused by the priming would be increased by the displacing of these tubes, inasmuch as a free passage would thus be opened from the sea to exhaust of low-pressure cylinder.

"Now as to the eccentric sheaves, straps, and rods, and the rapid wearing of the liners. The sheaves are of cast iron, the straps are of wrought iron, solid with the rods, which, by the way, are 26⅜ in. long, centre to centre, and not 22 in. as reported—for a valve with 7½-in. stroke—and are lined with a hard brass liner, 3¼ in. wide, ⅛ in. thick, laid inside the wrought iron straps, and free to move with the sheave. These have now been working two years in the Diamond and Sapphire, and in scores of other vessels, without complaint or trouble—why not in the Tourmaline? We attribute the excessive wear reported either to the relief rings at the back of the valves not being tight, and so allowing the full pressure of steam to be always in them while working, or in the anxiety to remedy the defective vacuum, the screws for adjusting the rings had been screwed up too tightly, and so produced undue load. The pistons are reported to have given constant trouble—how or in what manner we are not informed, only that the chief engineer put in some new springs and made them so tight that the engines could not be turned round.

"We cannot, of course, say anything as to the condition of the machinery when it left England; from the time of our handing it over in June, 1876, until now, with the exception of our attendance at the commission trial, we have not seen any part of it, but it is not the habit of the Admiralty to neglect the machinery of Her Majesty's ships, and we should expect it to be thoroughly efficient when entering on commission. We beg to append the several powers developed in the speed trials, the contract power being 2,100 indicated horse-power:—Diamond, indicated horse-power, 2128·825; speed, 12·978 knots; Sapphire, indicated horse-power, 2356; speed, 13·583 knots; Tourmaline, indicated horse-power, 2141·112; speed, 13·347 knots. You mention the Thetis as giving 2275 indicated horse-power, and the Turquoise as giving 2100 horse-power. The Tourmaline compares favourably with her sisters the Diamond and Sapphire, the trials of the latter having been made under exceptionally favourable circumstances as to weather, coals, &c.

"Now, as to your conclusions, you will pardon our taking exception to them entirely. You state your distinct opinion to be that bad design and bad workmanship are the causes which have led to the difficulties in these engines, and in proof state that a design must be bad which leaves the boilers entirely dependent on a single tank for their supply of distilled water; then surely nine-tenths of the engines afloat at this moment are of bad design, for few indeed have more than one hot-well or feed tank. You state a design must be bad which includes the driving of a valve 1¾ tons weight by a rod 22 in. long. This length, as already mentioned, is really 26⅝, but pray what has the length of the rod to do with the weight of the valve?—we can understand its being considered in relation to the stroke of valve, and taken in this sense the satisfactory working of the valves and eccentrics of the Diamond and Sapphire the last two years is a sufficient answer.

"The workmanship is not necessarily bad in the first instance when difficulty is experienced in getting a propeller down after a ship has been in dry dock for six or eight weeks, and subject to we know not what strains on her stern post. And a centrifugal pump bush is not necessarily a piece of bad workmanship if it seizes the spindle and runs round with it from neglect of lubrication. Following your remarks, and assuming that the story of the Tourmaline is true, we demur to your conclusion that she went to sea with her machinery defective in any way; the facts you adduce do not show it, and your arguments certainly do not prove it. In the consideration of this matter we have not only to deal with the condition of things when the vessel was lying at Sheerness a commissioned ship, we have to deal with this condition of things *entirely altered* by the vessel being put under steam and under the direction and management of a staff of officers, who may or *they may not* be able to manage the machinery put into their charge."

THE FUEL AND PROCESS EMPLOYED IN THE PRODUCTION OF IRON AND STEEL.

THE stimulus to mechanical ingenuity is in the hope of decreasing the existing cost of indispensable processes. It is perfectly futile to introduce an invention to a practical man on the ground of its ingenuity and novelty. His inquiry, before entering upon the subject, is, "Will it pay? What shall I save? What shall I gain?" If the inventor hesitates, or rather if he is not in haste to answer these questions, his visit will have a speedy termination, with some general remarks of courtesy that bring him no reward, and breed in him a depressing despondency. All the contrivance of men possessing any faculty for business must be judged by this test; and all the future prosperity of trade and manufacture depends solely on a combined determination to make the very best of all the resources that can be brought to bear.

Mr. C. W. Siemens opened his term of office as President of the Iron and Steel Institute by an official address, which cannot be given *in extenso*, but which contains much valuable information, and many valuable suggestions, from which we will condense sufficient to exhibit his views in the departments mentioned at the head of this article.

Labour is of course the most tiresome difficulty in all large undertakings. A half-penny an hour, or an hour less per day, makes a difference of much more than a profit in many large establishments; and the adjustment of contentious claims becomes the more difficult from the introduction of prejudice and passion. That source of trouble is in process of decline, but it will probably ever remain one of those elements, that can only be finally managed by strike, suffering and loss. It is a pity, because the interests are absolutely identical and ought not to be treated as if they were antagonistic.

Next in importance to the securing of honest labour at fair prices, that is, efficient and cheap labour in the production of iron and steel, comes cheap fuel. Fuel, in the widest acceptation of the word, may be said to comprise all potential force which we may call into requisition for heating and working the materials with which we have to deal. In a more restricted sense it comprises only those carbonaceous matters, which, in their combustion, yield the heat necessary for working our furnaces and raising steam in our boilers. It may safely be asserted that the great supply of the energy available for our purpose has been or is being derived from the great orb, which vivifies all nature—the sun. In the case of coal, it has been shown that its existence is attributable to the rays of the sun, which in former ages broke up or dissociated carbonic acid and water in the leaves of plants, and rendered the carbon and hydrogen thus separated from the oxygen available for recombustion. The same action still continues in the formation of wood, peat, and all vegetable matter.

The solar ray produces other forms of energy through the evaporation of sea-water, and the resulting downfall upon elevated lands; and through currents set up in the atmosphere and in the sea, which give rise to available sources of power of vast aggregate amount, and which may also be regarded in the light of fuel in the wider sense.

The form of fuel, which possesses the greatest interest for the iron smelters of Great Britain in this century, is the accumulation of the solar energy of former ages, embodied in the form of coal. It behoves us to inquire, what are the available stores of that most convenient substance. Recent inquiries have dissipated the fears about the probability of exhaustion, and from many sources we are able to compile a table of the coal areas and production of the globe, with an approximate correctness. These are:—

	Area in sq. miles.	Production in 1874. Tons
Great Britain	11,900	125,070,000
Germany	1,800	46,658,000
United States	192,000	50,000,000
France	1,800	17,060,000
Belgium	900	14,670,000
Austria	1,800	12,280,000
Russia	11,000	1,392,000
Nova Scotia	18,000	1,052,000
Spain	3,000	580,000
Other Countries	28,000	5,000,000
	270,200	274,262,000

We see then that roughly the total area of the discovered coal fields of the world amounts to 270,000 square miles. It also appears that the total coal deposits of Great Britain compare favourably with those of other countries in Europe; but that in the United States and in British North America there exist deposits of extraordinary magnitude, which seem to promise a great future for the New World. The Coal Commissioners in 1871 reported that there were then 90,207 millions of tons of coal available in Great Britain at depths not greater than 4000 feet, and in seams not less than one foot thick, besides a quantity of concealed coal estimated at 56,273 millions of tons, making a total of 146,480 millions. Since then 600 millions of tons have been raised up to December 1875, and calculation shows, with the present rate of consumption the store will last 1100 years. Statistics show that during the last twenty years there has been a mean annual increase on the output of three and a half millions of tons, and on that calculation our supply would last 250 years.

In comparing, however, our rate of increase with that of population and manufactures, it will be found that the additional coal consumption has not nearly kept pace with the increased demand for the effects of heat, and the difference is attributable to the introduction of economical processes in the application of fuel. In the case of the production of power, the economy effected during the last twenty years exeeds 50 per cent; and a still greater saving has probably been realised in the production of iron and steel in the same time. This may be gathered from the fact that a ton of steel rails can now be produced from the ore with an expenditure not exceeding 50 cwt. of raw coal; whereas a ton of iron rails twenty years ago involved an expenditure exceeding 100 cwt. Dr. Percy states that in 1859 one large work consumed from 5 to 6 tons of coal per ton of rails.

It is not unreasonable to conclude that the ratio of increase of population and of out-put of manufactured goods will be nearly balanced for many years to come by the further introduction of economical processes, and that our annual production of coal will remain substantially the same within that period, which, under those circumstances, will probably be a period of comparatively cheap coal.

This speculation leads to a further conclusion, which is, that our coal supply at a workable depth will last much longer than 250 years, if we take into account the probability of fresh discoveries, of which we have had notable instances, such as that in North Staffordshire, where a large area of coal and black-band ironstone is opened up on the estates of the Duke of Sutherland. Again, deposits are not only at moderate depths, but the quality of British coal is unsurpassed; and although coal and ironstone are not always together here, their separation is very small compared with other lands. We have

also the advantage of water-carriage for internal and for export purposes more available than others. These advantages ought to decide the contest for cheapness in supplying the markets of the world with iron and steel in favour of this country.

Coal assumes in many instances the form of anthracite. South Wales contains large deposits of this mineral fuel, for hitherto little use has been made of it for smelting purposes. When raw anthracite is used in the blast furnace mixed with coke, it should be limited to 10 or 15 per cent. or the furnace may become choked by an accumulation of decrepitated anthracite. This difficulty was overcome many years ago at Creusot, in France, by crushing the anthracite coal, and mixing it intimately with crushed bending coal, and then coking the mixture in equal proportion in Appold's vertical coke-ovens, yielding an unsightly but hard and serviceable coke. A similar method is employed in South Wales, and coke is produced containing 60 per cent. of anthracite, bound together by 35 per cent. of binding coal, and 5 per cent. of pitch or bitumen all broken up and intimately mixed in a Carr's disintegrator to being coked in the usual manner. Coke of this description possesses great endurance in the furnace and deserves the attention of iron-smelters.

In the United States of America anthracite is the only mineral fuel in the Northern States east of the Alleghanies, and is universally employed for blast-furnaces, heating purposes, and domestic service. It gives forth no smoke, and the very cities show in their brightness or smokiness the contrast between anthracite, as at Pennsylvania, and bituminous coal, as at Pittsburgh. There are vast deposits of anthracite in the Schuykil district, and there are excellent appliances and methods for working them. The American kind is less decrepitating than ours, but its superiority is the result of the various ways successfully adopted in its preparation for the market. The raw anthracite as it comes from the mine, is raised to the top of a wooden erection 80 or 90 feet high ; in descending through this it is subject to a series of operations of crushing, washing, sieving, and separation from slaty matter ; it is then delivered through separate channels into railway waggons, classed as large coal, egg coal, walnut coal, pea coal, and every kind is nicely rounded and of uniform size. The dust coal, which is the half, accumulates round the mine, awaiting the results of experiments made in hope of its utilization for steam-boiler purposes.

Next in importance to strictly mineral fuel are lignite and peat ; these are deposited in almost every country, and may be regarded as coal in formation. The chief drawback in their employment in lieu of coal is in the large percentage of water they contain, whereby in their crude condition it is impossible to produce high degrees of heat. But the difficulties are overcome by subjecting the wet material to processes of compression, dessication, and coking, and then excellent fuel and distilling products are obtained ; but the cost of operation exceed the market value of the result. Crude air-dried peat has been used for obtaining high degrees of heat for metallurgical and other operations by means of the regenerative gas furnace. It is important to observe that the carborific value of a ton of air-dried peat or lignite so used is equal to that of a ton of good coal, if an equal deduction be made in both for moisture and earthy matter. The carbon properties of peat yield a very rich gas for melting steel or re-heating iron, and the only precaution necessary is to pass the gas from the producer over a cooling surface sufficient to condense the aqueous vapour before it arrives at the furnace. But this is unnecessary with the older lignites, like those abundant in Austria and Hungary, which really are equal to good coal, except for blast furnace purposes.

Fuel also occurs naturally in the gaseous condition, as every miner knows too well ; but occasionally it is found separate from its primary association with coal, and then has been utilized for fuel. At Baku, on the Caspian, natural gas has issued from the ground for centuries, and the column of perpetual fire has served the purpose of giving the Parsees a holy shrine at which to worship their deity. In Pennsylvania a more practical application has been made of the gas issuing from borings in providing fuel for working the pumps and lighting the district. The quantity so obtained can be estimated from the fact that one of these borings, after discharging all it could into the atmosphere under a pressure of not less than 200 lbs. to the square inch, has lately been connected by a 5 in. pipe with Pittsburgh—a distance of eighteen miles—and then worked successfully seventy puddling and re-heating furnaces. Even this gives only an imperfect idea of the calorific power in a single issue of natural gas, inasmuch as the combustion is carried on in the furnace in the most wasteful way, the gas being imperfectly mixed with cold air, and converted thereby into dense masses of smoke. Analysed it gives—

Hydrogen,	13.50
Marsh gas,	80.11
Ethylene,	5.72
Carbonic acid,	0.66

Although the use of a natural gas is not likely to assume large proportions owing to its rare occurrence, its application forcibly reminded Mr. Siemens of a project he put forward many years ago, namely, to erect gas producers at the bottom of coal mines, and by the conversion of solid with gaseous fuel, save entirely the labour of raising and carrying. The gaseous fuel in ascending would acquire an onward pressure from its temperature and low specific gravity, sufficient to propel it through pipes or culverts to a considerable distance, and it would be possible to supply townships with heating gas for factories and for dwellings. A company was formed at Birmingham in 1869 to supply that town with heating gas at the rate of sixpence per 1000 cubic feet, but the project was defeated in Parliamentary Committee by existing gas companies on selfish grounds. It lies by for the present, to be revived in due time.

Fuel also occurs naturally in the liquid state, and if mineral oils could be obtained in quantities at all comparable to those of solid fuel, liquid fuel would be preferred because of its purity and superior calorific value. But it is rare and dear, comparatively, even in the oil districts of Pennsylvania and Canada, and its use for smelting need not therefore be considered.

In our general definition of fuel is included the evaporative effect of the sun's rays, by which sea water is raised to the highest levels, whence it descends to the sea, and in so doing can be made to impart motion to machinery. This form of fuel, which takes the place of coal, otherwise extended in raising steam, has been resorted to in all lands since civilization began. The industries of the world were thereby scattered, and compelled to seek location in valleys or in mountain gorges in order to use the stream to drive the saw or flour mill, the trompe of the smelter, and the iron and steel manufacturer.

The introduction of the steam-engine within the past century changed all this, and caused manufactories to be massed in great centres, which tendency has been further increased by canals and railroads, enabling us to bring raw material from the place of its production to its employment, and distribute the result all over the world. But a reaction in this centralizing process may set in from the circumstance that competition may compel us to have again recourse to the natural forces neglected in times of prosperity and hurry, and to produce cheaply under improved but essentially old conditions. Especially is this the case in continental countries that have large plateaus, such as Sweden and America : and it is of interest to calculate the magnitude of power which is now for the most part lost that may be sooner or later called into requisition. Take as a familiar example the Falls of Niagara, the estimated amount of water of which is estimated at 100 millions of tons per hour : its perpendicular descent may be taken at 150 feet, without including the rapids, which represent a further fall of 150 feet, making 300 feet between lake and lake. The force represented by the principal fall alone amounts to 16,800,000 horse-power, a force which, if produced by steam, would demand the consumption of 260,000,000 tons of coal per annum, taking the coal at 4 pounds per horse per hour. In fact, all the coal raised throughout the world would barely suffice to produce the amount of power that continually runs to waste at this one great fall. It would not be difficult to utilize a great proportion of this power by the use of turbines and water-wheels, erected on the deep river shores below the Falls, supplying them from canals cut along the edges ; but it would be impossible on the spot, from the absence of mineral wealth there and other inducements, to establish factories.

In order practically to render available the force of falling water at this and thousands of other places, there must be devised a practicable means of carrying the power to a distance. Sir William Armstrong has taught us how to carry and utilize waste power at a distance through high-pressure mains, and at Schalthausen in Switzerland, and other places, it is conveyed by means of quick-working steel ropes passing over large pulleys. These means avail for distances under two miles, and time may reveal effectual means for covering longer distances ; indeed, one is now worthy of consideration, namely, the electrical conductor.

Suppose water power to be employed to give motion to a dynamo-electrical machine, a very powerful electrical current results. This can be carried to a great distance through a large metallic conductor, and these impart motion to electro-magnetic engines to ignite the carbon points of electric lamps, or to effect the separation of metals from their combinations. A copper rod of 3-in. diameter could transmit 1000 horse-power thirty

miles : an amount sufficient to supply 250,000 candle powers, or enough to light a moderately sized town.

The use of electrical power has sometimes been suggested as a substitute for steam : but it should be borne in mind that as long as the electric power depends on a galvanic battery it must be more costly than steam power, for the combustible consumed is zinc, which is much more costly than coal. The question assumes a totally different aspect if a natural force not otherwise available could be employed for the production of an electric current. But that we have to wait for—at least the method of doing it.

We come now to the question of *Processes* by which crude iron ore is converted into such materials as leave our smelting works and forges : those processes by which iron is made to attain its highest qualities, both as regards power of resistance and ductility.

The credit of producing cast-steel upon a working scale, is due to Huntsman, who first accomplished its fusion in crucibles placed amongst the coke of an air furnace pouring the metal in a fluid state into metallic moulds. This is still done at Sheffield for special qualities of steel, such as that for tools, tires, castings and forgings : a ton of cast-steel in ingot is produced from using 2½ to 3 tons of Durham coke. At Pittsburgh—where is carried on large operations of pot melting, plumbago pots of double the size of the clay pots of Sheffield are invariably used. Eighteen or twenty of these, each containing 1 cwt. of metal, are placed in a furnace, and they will bear charging five times in twenty-four hours before they are worn out. One ton of small slag is required to one ton of steel melted, and this is delivered to the works at the small price of 30s. per ton. With such advantage, what does the American need of protection? Surely he should meet his Sheffield competitor in the open market.

Great advances in cheapening production have been made by the invention of Bessemer steel, and out of it is continually coming various methods in detail tending to the same end. At Creusot and other continental works, a system of direct working, or of transferring the pig metal in the molten condition from the blast-furnace to the Bessemer converter, has been introduced, which method has recently been adopted in several of the leading English works. By this, the fuel usually employed in remelting the pig metal in the cupola—say 2½ cwt. per ton—is clearly saved, and other advantages are realized ; but the Bessemer converter is made to depend upon the working of the blast-furnace, both as regards time and the quality of the metal resulting. At Barrow and other large works this objection does not appear to have any force worth mentioning, but it remains to be seen whether any practical advantage can be realized by this method of working at smaller works, where a change in the working of the blast-furnace from Bessemer to forge pigs would cause a serious interruption in the working of Bessemer plant.

In America, Mr. Halley has indicated plans for saving labour by increasing indefinitely the number of blows per day from each converter. At the North Chicago Steel Works seventy-three blows had been attained in one pit during twenty-four hours, but it is doubtful whether such a rate could be maintained for any length of time. The Americans do not appear to have adopted the direct process of working, but are content to re-melt their pig metal in large cupolas in immediate proximity to the converters. The capacity of the converters has been much increased of late, and the degree of heat engendered by an increased blast power been augmented so much that a considerable amount of scrap can be remelted in the fluid-bath before discharging it into the ingot moulds.

While the Bessemer process has been making rapid strides, a rival process has gradually grown up by its side, known as the open-hearth steel process in connection with the names of Mr. C. W. Siemen and Messrs Siemen and Martin. It is not a new idea, for it is that of the ancient Indian as old as cast-steel itself. Wootz, as it was called, was the result of a fusion of a mixture of malleable and cast iron. Reaumur, Heath, Gentle, Brown, Richards and others in recent days have improved thereon in several ways : but it was in 1856 when Mr. Siemen and his brother Frederick gave their attention to construct a regenerative gas furnace that C. W. Siemens perceived the adaptation of the furnace to the production of steel upon the open hearth, and proposed it to Mr. Darby of Ebbw Vale in 1861. He issued licenses to two friends to use his patent, and for four years these did their best, but without commercial success. They could get the steel, but could not reduce the price. Siemens thereupon did as Mr. Bessemer did at Sheffield, started experimental works of his own. Another licensee, Messrs Martin of Cereuil succeeded in producing steel by dissolving wrought iron and steel scrap in a bath of pig metal, and Mr. Siemens in producing steel by the use of pig metal and iron ores.

The open-hearth system has the advantage of not depending on time for the results. The heat of furnace is such that the fluid bath of metal after being reduced to the lowest carbonization may be maintained there for any reasonable time, during which samples may be taken and tested and such additions made for its adjustment to the desired quality by the use of pig metal, wrought scrap, spongy metal or ore. Ferro-manganese is then added in the requisite proportion, and the result is a bath of metal of known chemical condition, which can be "dead melted," and this renders it applicable for certain purposes not hitherto within the possibility of pot steel.

This process has its best results when treating scrap and old iron rails, converting them into steel. These converted rails have worn ten years and are still down at Paddington. Ferro-manganese, the chief factor in this treatment, was introduced into the market by Mr. Henderson of Glasgow, and was originally produced by changing carbonite or oxide of manganese and manganiferous iron ore intimately mixed with carbonaceous matter, upon the open hearth of a Siemens furnace, with a carbonaceous lining. The demand, however, was insufficient for profitable working, and it was not until 1875, when the Terre-noire Company put it into the market that public attention could be gained.

When added in the proportion of ·5 per cent. or more to steel, or ingot metal, containing only ·15 to ·20 per cent. of carbon, Manganese has the effect of removing red-shortness, and of making it exceedingly malleable both in the heated and cold conditions. In using spiegeleisen containing only 10 to 15 per cent. of metallic manganese, it is impossible to produce this malleability, without adding at the same time such a percentage of carbon as would produce a hard metal. The use of ferro-manganese overcomes that difficulty and greatly facilitates the production of a metal, so malleable and with so little carbon, as to remain practically unaffected in its temper, when plunged red-hot into water.

Another result produced by the use of manganese without carbon, upon mild steel, or ingot metal, is to neutralize the objectionable effect of phosphorus, provided it does not exceed ·25 per cent. This metal, which may be said to take the place of carbon, presents a large specular fracture ; and is contrary to what might be reputed extremely ductile when cold.

Iron, when in the fluid condition, can be alloyed with other metals, and some of the compounds thus formed are known to possess very remarkable properties. Thus, iron combined with 3 per cent. of tangsten, and ·8 per cent. of carbon, yields a metal which can be worked like ordinary steel ; but which, when hardened, retains magnetism to a very remarkable degree. A further addition of tungsten produces an exceedingly hard metal, which cannot be forged, but which, when cast into bars and ground to form sharp edges, produces cutting tools of great endurance.*

An admixture of chromium has for many years been known to yield steel of great hardness and strength, but it has only recently been brought into practical use under Mr. Julius Baur in America, and Sir John Brown and Co., of Sheffield. These claim for it very remarkable properties as regards strength, malleability, and freedom from corrosion.

The formation of compounds such as these, is a matter of great interest in connection with the future development of the applications of steel, and is one of those subjects which can be much advanced by organised research under the committee of the Iron and Steel Institute.

The value of the material known as mild steel or ingot metal consists in its extreme ductility under all possible conditions. Its ultimate strength is much inferior to that of ordinary steel, and rarely exceeds 28 tons per square inch ; its limits of elasticity is reached at 15 tons per square inch, whilst the limit of elasticity of a harder steel may reach from 25 to 30 tons, and that of hard drawn-steel wire from 45 to 50 tons. But in estimating the relative value of these different materials by the amount of work that has to be expended in causing rupture, it will be found that the mild steel has the advantage over all its competitors. When subject to blows or sudden strains, such as are produced by the explosion of gun-cotton or dynamite, extra mild steel differs in its behaviour from that of B. B. iron and ordinary steel by yielding to an extraordinary extent without fracturing, and it is in consequence of this non-liability to rupture, that it may be loaded to a point much nearer to its limit of elasticity, than would be safe with any other material.

* Mr. Mushet is the maker.

JUTE.

THIS natural product has a history without a parallel. From being a mere waste out of which packing bags or sacks were made, it has become in some sort a rival of silk in many highly finished descriptions of goods, and fetches prices equal to those demanded for Sunn or Bengal Hemp. It consists of the fibres of two plants called the houch and isbund extensively cultivated in Bengal, and as a commercial article comes into competition with flax, tow, and codilla in the manufacture of carpets; but it is very brittle and hard, snapping if tied in a knot, and it soon rots if kept wet.

The word jute is derived from the common vernacular names of the fibre in several districts—*jhout and jhot*—anglicized into jute. The leaves of the plants are extensively used as pot-herbs by the people, and both kinds are alike in appearance, leaf, colour, and growth, but differing in their seed pods. They are both annual, and grow from five to ten feet high with a stalk about the thickness of a man's finger, seldom branching until near the top.

Jute has been cultivated from time immemorial for home consumption, but the export dates only from 1850, since when the trade has assumed enormous proportions. The plant has acquired a position in East India Government affairs second only to that of salt, and as it is found indigenous in 47 out of 58 districts, advantage is being taken to improve the soil and promote the culture in order to develop its wealth to the uttermost. The commission appointed to this end found in the early stages of their labour that the choice of seed had been conducted in the most careless manner, and often taken from the worn out stunted wayside specimens. This, and the change of seed, has the attention of Government. and there is no doubt that the future of this useful plant will be as progressive as it has so strikingly been. In fact, there is danger of its injuring the food-supply by occupying land hitherto devoted to that object. Two thirds of the 921,000 acres now under jute cultivation were formerly food-producing lands.

We have said that its original use did not, in former times, extend beyond bag making (gunny bags), and mixed with hemp or flax for cordage and twine: but now the paper maker, the silk manufacturer, the scarf manufacturer, share with the rope maker the imported supplies. Our notice of the subject must be limited to a few points concerning its treatment and uses, and these will not be devoid of interest.

The seed is sown broad cast and covered with a slight crust of earth by a harrow, but the land should be deep ploughed, situate in a plain, in order to have all the effect of moisture and sunshine, for these alternating conduce to its rapid growth. The harvest is in July and August, the stalk being cut near the root with a bill-hook. These stalks are made up into bundles as big as a man can carry and thrown into water where they remain for several days. They are then beaten until the glutinous substance in the bark is washed away, when the fibres partially detach, and they are stripped from end to end. The fibres are then hung up to dry in the sun for a few days, and finally made up into hanks for the market. The cultivation is carried on by the ryots themselves, who often form themselves into co-operative guilds for that purpose. Every part is of service. We named its leaves as a food-vegetable, they are also used for manure; the reed is employed for fencing and for fuel, the seed for oil-cake, and the root for paper.

The quantity of jute exported from Calcutta was in 1828 364 cwts., and of the value of £62. The extraordinary increase that has since taken place is entirely due to the energy of the ryots of Bengal, who finding it profitable, engaged therein with alacrity and created a trade. The large import of cheap Russian flax at first kept down the demand here for jute, but that supply failed in the war of 1854, and then jute came into favour. The ryots seized every opportunity without any prompting or assistance. From 1858 to 1863, the average annual export from Calcutta was 967,724 cwts. From 1863 to 1868 it had risen to 2,628,100 cwts. The quantity of raw jute exported in 1872-3 was 7,080,912 cwts., worth £4,142,547, an increase of nearly a million of cwts. in one year. Thus the ryots have created and extended an industry in forty-five years to a value of more than 4½ millions sterling, without any official encouragement or aid whatever. More than four millions of cwts. are imported into this country, and almost entirely used by Dundee, where a double trade has sprung up: the one, jute manufacture, and the other, the Arctic whaling trade; the one is necessary to the other, for the oil required in large quantities in the treatment of jute, must be of the whale, and Dundee is the best port for Arctic whaling vessels. It is very remarkable how industries carried on at vast distances act upon each other. The growth of Jute in Bengal led to its manufacture in Dundee, and this caused the revival of the whale fishing in Baffin's Bay. Jute is worked up cheaper there than anywhere else, and the oil finds an instantaneous market at full value.

Beside the agricultural care at length bestowed on the cultivation of jute, such as proper manuring, choice of seed, judgment in its harvesting, and a more scientific method as to steeping in order to promote fibre and colour, modern machinery is doing very much to improve the quality and increase its variety of usefulness. Of this matter we shall speak before closing this paper.

The treatment required varies in every locality, because of the special character of the plant, or because of the nature of the water in which the steeping is done. The process requires in some cases two or three days, in others from twenty to thirty. There is also a difference necessitated by the purposes for which the jute is to be applied. Stagnant water is best for strength, running or tidal more suited as to colour. Then, again, jute ripens when everything is ripe, and is not harvested at exactly the right time, because the growers' hands are full, and he cannot afford to buy extra labour at such times. But in all cases it is essential that steeping be not overdone, and too much importance cannot be placed upon the fact, that the cutting at the proper time determines the quality; instance, jute for cordage ought to be cut in seed, but for weaving it should be cut in flower.

The employment of machinery for separating the fibre cheaply and effectually has long been felt to be very desirable, and Government premia have been asked as in the case of Rhea, or China-grass. The conditions of such machines were defined by a commission as—first, it must be so cheap as to be within the reach of the majority of the cultivators, and these are poor; second, it must be so easily worked that ordinary ryots would be able to use it; it must be so simple that a village smith could repair it, if any accident occurred.

There are three ways of producing cordage from jute; the range is great from the thinnest twist, such as is fit for weaving, to thick ropes for hawsers for large boats; the intermediate grades being twines and cords of various degrees of thickness, adapted to the different economic purposes for which such articles are required.

First: A small bundle of fibre is either tied at some elevation to a post, or suspended from some parts of the roof. Filaments according to the desired thickness are detached from the lower part of the bundle, tied to a reel, and are spun from left to right until twisted. These are made up into a ball. Second: An instrument is employed called *tákún*, which is turned upon the thigh or the sole of the feet; and, third, another machine similar to that used by sailors in spinning such yarn as may be required in a voyage.

The first makes twine of moderate thickness for cords which can be doubled or otherwise multiplied; and from such twines coarse cloth is produced. The second is especially adapted for making twist for weaving fine cloth. The third is for thick ropes of twelve to twenty fold in thickness, such as are seen in use for bales of merchandise.

Jute is to India more than hemp is to us. Hemp is there also, but Jute is the more useful. Gunny cloth is the general term that describes the product, and there are many kinds. The thick, close-woven gunny alone has nine varieties, each of them also having three commercial qualities. No. 1 packs rape-seed, linseed, poppy-seed, small grains, and sugar. No. 2, rice, vetches, and seeds of larger size than linseed. No. 3 for double packings. The next is used as a thin, closely-woven fabric, common among the aboriginal tribes, and used as a garment by the poorer classes of women. This is often mixed with cotton, and for wearing apparel is sometimes dyed white and red in stripes. The last is used for making sails for country boats and outer covering of large packages of coarse fruits.

The method of weaving coarse gunnies is thus described by Babu Ramcomal Sen:—"Seven sticks or weaving posts—a warp—are fixed in the ground occupying a length equal to the size of the piece to be woven, and sufficient twine or thread is wound on them as warp. The warp is taken up and removed to the weaving machine. Two pieces of wood are placed at the two ends, which are tied to the roller and fastened. The treadle is put into the warp, next to a thin piece of wood for regulator. No shuttle is necessary; in its stead is a stick covered with thread which is thrown into the warp as woof, and beaten in by a piece of plank, and as the cloth is woven it is wound up to the roller. Another piece of wood smoothes the woof, and a stick is fastened to the warp to keep the cloth straight."

FIG. 1
SECTIONAL ELEVATION

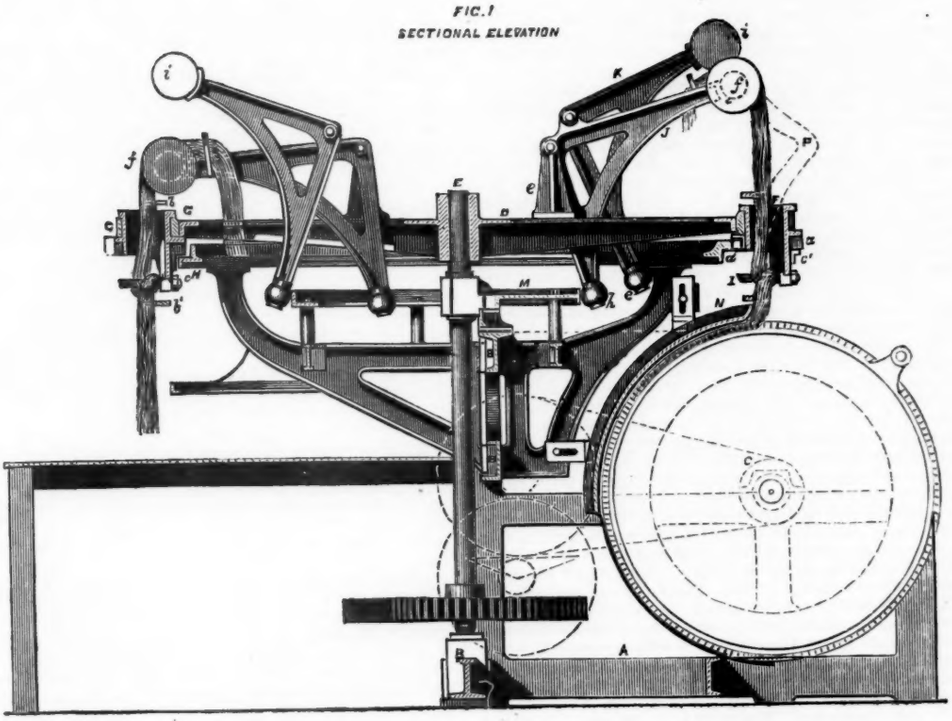
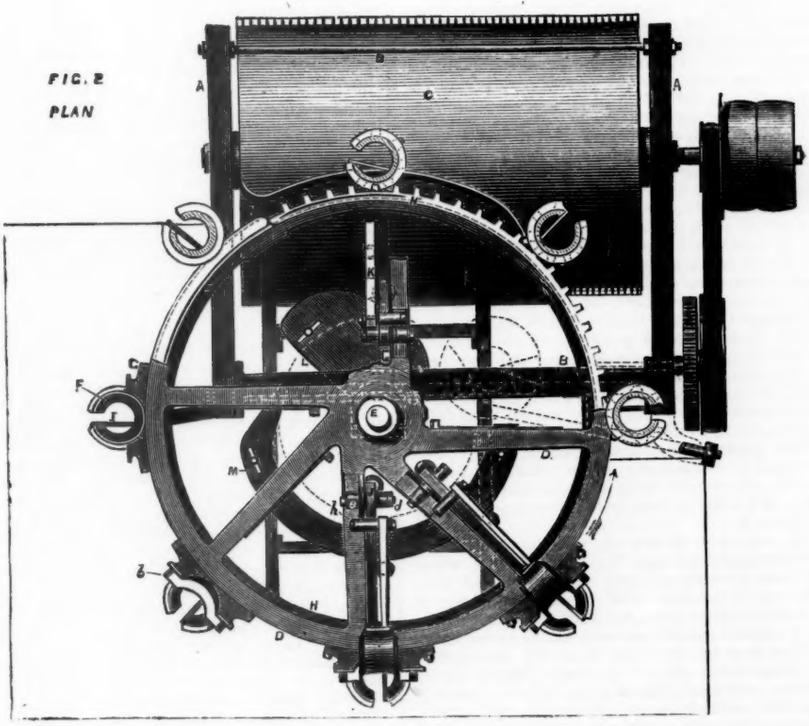


FIG. 2
PLAN



Foreign implements and machinery are, however, gradually superseding these primitive contrivances, and English machinists could not do more beneficent or profitable work than by supplying small workable or not-too-dear machines. In this regard we have now to notice the recent invention of Messrs. M'Kean and M'Grath, as exhibited at Sir W. Fairbairn's works at Leeds, he having been the manufacturer. It is a machine for cleaning the ends of all long vegetable fibre, especially that of jute, the root end of which is very heavy.

We have described the methods adopted to separate the fibre and its being "bundled" for shipment at Calcutta; we have noticed the varieties as to coarseness and fineness produced by the nature of the soil. There is a coarse red fibre on the lower part or butt of the stalk, which, in the best sorts, is cut off to the length of 10 or 12 inches. These butts are mostly used for paper making, because, although fibrous, it has no length fit for the spinner except for coarse sacking, wherein the low price tempts the manufacturer to use a portion in that way. The practice of cutting is wasteful, for it shortens the spinning material; the operation is done carelessly by the natives; and rather than submit to such losses, the growers prefer to take a lower price than the market demands, rather than have the labour and loss accruing from the old ways; and lastly, the practice of cutting the ends square off necessitates a combing in order to get the fibres into the weaving machine. This combing ought to be done in India, and to carry out that idea, these gentlemen have invented special machinery.

On the preceding page we illustrate, by the courtesy of the editor of the *Engineer*, the machine of Messrs. M'Kean and M'Grath, very simple in design and construction, containing few details, and economic in its cost when new, and when under repair. Fig. 1 is a sectional elevation, and Fig 2 the plan. AA is the main side framing of the machine. C is a cylinder covered with pins or teeth varying in length, strength, and pitch, the coarsest pitch being at the "entering" end of the cylinder, which operates first upon the fibres, and the finest being at the finishing end for delivery. D is a large wheel or carrier secured to the vertical shaft E, and made to revolve slowly in the direction indicated by the arrow. On the periphery of this carrier wheel is a series of holders F, which are free to revolve in the bearers G attached to the carrier. The holders F are provided with a set of cogs *a*, which gear into corresponding cogs on a segment of the fixed ring H, which imparts to the holders a rotary motion, whilst the streaks of fibre held by them are being operated upon by the cylinder C. Attached to each holder is a pin I, round which the "streak" of fibre to be operated upon is hitched. On the outer part of the bearers G, and between two of the cogs on the holders F, are openings which admit the streaks of fibre into the centre of the holders. Above and below the holders are fixed guards *b* and *b* 1 to retain the streak in proper position. Projecting from the holders are two horns *c* and *c* 1, which slide against a plain part of the fixed ring H, and thus prevent the holders from turning when no longer in gear with the cogged segment; whilst in this position the openings in the holders are in a line with those on the bearers G. J is one of a series of bell crank levers placed opposite each holder; these work on studs *d*, on the standards *e*, supported from the carrier D. Attached to the outer limb of these levers J are fixed flanged rollers *f*, over which the upper portion of the streaks are placed, and then inserted between the fingers of clips also carried on the side of the levers J. The outer limb of these levers carries the studs *h*, on which work other bell crank levers K, the outer ends of which carry fixed rollers *i*, which rest upon the flanged roller *f*, then fixing the upper end of the streaks. These rollers or holders are covered with india-rubber, to increase the firmness of their grip. At the extremity of the inner limb of the levers J are friction rollers, which act against a fixed eccentric L, as the levers are carried forward by the carrier D. This eccentric is so formed and placed that, acting through the levers J, the grasping rollers *f* and *i* rise gradually and increase the distance between them and the holders F, whilst the latter are revolving during their passage with the streak over the cylinder.

After the holders have passed over the finishing end of the cylinder these rollers rapidly descend. That portion of the streak between the pin I and the rollers, having received a twist from the rotation, is by the sudden descent of the rollers doubled, as shown by the dotted line at P, and takes a twisted form, thereby greatly facilitating the removal of the streak by the attendant.

At the ends of the inner limbs of the levers K, are friction rollers E, which, immediately after the descent of the grasping rollers *f* and *i*, come in contact with a fixed eccentric M, causing the top roller to rise from the lower; the liberated streak is then removed, and another introduced. The fixed rollers *i*, descend into their former position on the rollers *f*, immediately before the holders F commence to revolve on their own axes. A saddle N, is fixed over a part, and near to the periphery of the cylinder, between which and the latter the jute passes, and is kept in contact with the combing tooth.

The inventors claim that their machines worked in India would greatly increase the quantity of jute for shipment in a given time, and ensure greater regularity in quality and quantity. Moreover, the value of the material is enhanced by its being thoroughly combed and with a "switch" end instead of a cut one. As also the material taken off is converted into tow instead of being left as cuttings, value there is increased and the waste can be used in India.

The total gain is shown to be about £3 per ton, and as the machine can comb a dozen tons a day, and thereby save £36 a week, it cannot be otherwise than a blessing to the jute industry in India.

THE PORCELAIN MANUFACTURE.

THE manufacture of Porcelain in England began about the year 1750. But as we have noticed in a previous article, Nov. 1876, on the Persian Exhibition at South Kensington, that nation, and also China and Japan, possessed the knowledge centuries before. Some specimens of the date A.D. 800 have never since been surpassed; they have not been equalled. The secret cannot be recovered by our best manufacturers at present. In the tombs of Thebes have been discovered bottles of Chinese manufacture, of inferior finish, which appear, from their inscription, to have been made 1400 years B.C.; but the art reached its highest in that country at about the same period as in Persia, A.D. 1000. The wonderful tower of Pekin, composed of porcelain, was built in the year 1277. That is necessarily a gross production compared with the beautiful examples from the same material in subsequent times; and it must be confessed that in China and Japan, although the material became refined to the very highest degree ever yet attained elsewhere, the design and ornament were simply hideous and monstrous.

After centuries of attempts in Europe, the art was at last recovered by what may be called an accident. One Böttcher, a devotee to chemical investigation, acquired such a distinction as to lead his generation to suppose him to be a servant of the Enemy of Man; he had to fly from Berlin to Dresden, where dwelt Augustus II., the elector of Saxony, whose love of chemistry had its inspiration from an idea he had that all things could be turned into gold. He employed this man to seek after the philosopher's stone, and during his experiments in crucible-making for that purpose, it was found that some of his crucibles, when heated, had many of the characters of eastern porcelain. Böttcher's discovery pleased the ruler so far as to secure him a liberal table, and all the elegancies of royal hospitality, but he became a prisoner in order that the secret should never be divulged. Experiment after experiment followed, with alternations of hope and disappointment to the royal jailor, but without disturbing the cheerfulness of the captive chemist. Furnace work of sixty successive hours, ending in nothing, daunted him not; he built others requiring 120 hours, and ultimately—two years—produced a white porcelain. It cracked. The Elector determined on this to erect a proper factory at Meissen, for he pre-visioned success, and made Böttcher the director thereof. About six years after that, an iron-master in that district discovered by accident a very fine white clay in that neighbourhood. He was out riding, and his horse slipped, leaving a deep foot-mark which disclosed the character of the soil. It occurred to him that this material might, from its intense smoothness, be, by drying and pulverizing, a source of revenue if prepared as a substitute for hair powder, then universally employed by all people of condition. Böttcher's valet bought this cheap stuff, and made his master's wig so heavy that it gave him discomfort. He inquired, therefore, and learned the cause. He instantly saw that this new substance must be of mineral origin, and on making experiments, found that his long-desired natural supply was in this offensive hair powder deception.

"Schnorr's White Earth" was directly placed under the catalogue of forbidden exports, and all persons working between the pit and the factory, and therein, were bound to an oath of secrecy. In every room hung the motto, "Be secret to death," and month by month the oath had to be renewed, and even the King, as a visitor, was compelled to swear it. Naturally, the workmen became conscious of some source of concealed wealth, and a few stray barrels found their way into the hands of other kings. One of the men ran away to Vienna, and sold his honour for gold. Rival factories sprang up in different parts of Germany without eclipsing the parent; but now all has changed.

The ancient glory has gone the way of mundane affairs, and England has a hundredfold better establishments on view to any intelligent visitor than ever the protective seclusion of selfish autocracy could furnish.

And England heard of these proceedings, and pondered them to purpose. The rivalry existing on the Continent induced her to attempt a share in the list of competitors. White sticky clay could be no exception to the general geological law whereby we believe in the diffusion over almost all the globe of every kind of the substances which in total make up our earth; and it occurred to some here that a little examination might enable us to introduce and establish a like new source of wealth from natural elements, such as Germany had found. Hence, at Bow, at Chelsea, and at Derby, factories were established, and to repeat our first remark, "the manufacture of porcelain in England began about the year 1750."

We will in this paper speak more particularly of that at Derby. After forty years' existence, it is thus described by Mr. Hutton, a valuable contributor to topographical literature, and a bookseller, of Birmingham, in 1791—"There is only one manufactory, and that employs seventy people. The clay is not of equal fineness with the foreign, but the workmanship exceeds it. The arts of drawing and engraving have amazingly improved within these last thirty years. The improvements of the porcelains keep pace with these. They adhere to nature in their designs; to which the Chinese have not attained. A dessert service of 120 pieces was recently fabricated here for the Prince of Wales. The spot upon which this elegant building stands, which is internally replete with taste and utility, was once the freehold of my family. It cost thirty-five pounds; but the purchaser, my grandfather's brother, being unable to raise more than thirty-eight, mortgaged it for seven. Infirmity, age, and poverty, obliged him to neglect the interest; when, in 1743, it fell into the hands of my father, as heir-at-law, who, being neither able nor anxious to redeem it, conveyed away his right to the mortgagee for a guinea."

This factory is described by Mr. Glover in 1833 as then situate on the Nottingham Road, and occupying an area equal to 6,000 square yards, affording sufficient room for the employment of 400 workmen,* and having a frontage of 170 feet. The works were taken up in 1871, and were then carried on by Mr. Robert Bloor, who erected a steam engine, added new glaze and biscuit kilns, and made other improvements to accelerate production, and increase the beauty and durability of the ware.

We have mentioned this factory at Derby in preference to the others, because of the circumstance that, although those at Fulham or Chelsea and Bow have an anterior date, they were commercial failures, and all the property, models, designs, and workmen, were absorbed by the Derby works, which were established by Mr. Duesbury. The foreign manufacturers conspired to ruin the Englishmen at Chelsea and Bow, by taking advantage of a customhouse regulation, and they succeeded; but Mr. Duesbury was too much for them.

The Derby porcelain works, when conducted by Duesbury, were visited by Dr. Johnson in 1777, at which time the prices were extravagant. The old man deemed the China very beautiful, but too dear, for that he could have vessels of silver of the same size, as cheap as what were those made of porcelain. The charm lay in this; it was very transparent, of fine quality, characterised by a beautiful bright blue, which was usually introduced on the border or edge of the tea-services, the ground being in general plain.

These works were erected for the purpose of manufacturing cream-ware and earthenware, and both were made there for a short time. The cream-ware was scarcely inferior either in fineness of quality of paste, or in design and execution, to Mr. Wedgwood's cream-ware.

In making observations respecting this obsolete source of trade, let us notice the variety of persons employed thereupon. A manager, a traveller, and clerk there were of course. Then comes a "body mixer"—the man who compounds the paste. He is followed by a score of potters, half a dozen figure makers, called ornamental repairers; a dozen painters, half a hundred gilders, a half score of women painters, three dozen burnishers, a pair of biscuit kilnmen, another of glaze ditto, and two enamel finishers, with one glaze dipper, whose duty it was to make the work acceptable to the market. Herein the reader will see the proportion of artists required in these beautiful productions, and can judge by that measure the talent of the thousands of English men and women in our time, whose lives are devoted to such toil, not in Derby, nor in Chelsea, nor at Bow, for those factories are gone for ever, but in the great works at Etruria, Burslem, and Worcester.

The kind of work done at Derby was chiefly of the cream-colour, but it had fame for the dessert ware, commonly known as the Coventry pattern, from having been first made to the order of Lord Coventry. It had a light, or yellow green border, with three medallions or compartments, in which were painted small groups of flowers. The like device applied also to tea services. The painters had 2¼d. each group, and the work had to have two fires or burnings for flowers, landscapes, fruit, and the like. First the subject was sketched, and "washed in," which made it half done, and was so paid for. It was then fired, and afterwards finished, and fired again, the gilding being usually done between the first and second burning. Sometimes flowers were painted at one fire; that is, they were washed in and finished at once, but that method not being accounted good work, did not command a like reward.

The peculiarity of the Derby Factory consisted chiefly in Mr. Duesbury's determination to manufacture English china by Englishmen, and to engage the best English artists, such as Flaxman and Bacon, to obtain designs. This has of late years been much changed, because of the intrusion of foreign workmen and foreign designers; but our modern schools of art will soon restore the national reputation, and help to individualise a positive English style. A custom prevailed then which ought to be revived. The workman's name was attached to the work. All that is now produced bears Copeland's or Minton's, or other names of honour; but the skilled hand they have employed is unknown and unhonoured. The Derby Factory is famous only through the identity of the workmen who were there employed: Comptin, and Banford, and Withers, common men in their way, are immortalised; they are known to connoisseurs much better than is the employer, Mr. Duesbury. So was it with Billingsley, whose fragile work is almost priceless; so rare, so delicate, and so perfect. The workman's name is honoured, although, as a man, he had no worthy reputation. Flower painting from nature appears to have been an exclusive occupation to Withers, and Billingsley, and Boreman, and their several styles are well known. There are two scent jars in the South Kensington Museum, with pale yellow grounds, on which is arabesque scroll-work in black; the wreaths of flowers round the covers are attributed to Billingsley. They do not possess either the care or delicacy of his early manner—the foliage is coarse, and the roses for which he was very famous, flat; but the work has a rich appearance.

At the South Kensington there was exhibited from 1871 to 1875 a unique specimen of Billingsley's work called "The Prentice Plate," which had been in the local Derby Exhibition in 1870, and is thus described:—"They are remarkable examples of flower painting, true in form, colour, and grace of outline, whilst the soft bloom which gives the last charm to the beauty of flowers is wonderfully rendered. "The Prentice Plate" is surrounded by a border of roses, represented in every imaginable position, and every one distinct and remarkable. The stems are graceful, and elastic, and life-like. This relic had a history. When the factory broke up in 1848, it went for broken crockery, and was bought in Lisle Street, Leicester Square, for two shillings. It is now too precious to be sold. A workman can pore over it for hours, and every atom of its ornament is alive with suggestion, and almost over-mastering for its skill.

There was a fashion in this Derby house of making representations of public buildings, or seats, or churches, taken by the china painter from nature, and by his own hand reproduced upon the china. Farmhouses, and whatsoever pleased the workman of skill, graced these productions of their hands, and are invaluable. We produce by lithographed patterns an infinitude of repetitions, but these never made two alike; and it is just that kind of work that will soon be of inestimable worth. The world is weary of re-productions; it thirsts for new creations. These new creations will come, for we are beginning to recover the secrets of nature our ancestors possessed; we shall soon learn where is the best clay, and what is the best method of compounding it with other elements.

But it is curious to run over the lives of these men as collected by the industry of Mr. Haslam. Hill painted landscapes. He had lost the first three fingers of his right hand, and had to hold his brush between the stumps of his fingers. His landscapes, painted under such difficulties, were in great estimation, and found a ready sale. He did also a little horse-dealing, and rented fields, where thirty horses ran to grass; and from his eccentricities he became known as Jockey Hill. Rough as were these men, their work was quiet and subdued. Their method was to model, or technically, "wash in" the subject in neutral tint, over which they laid the positive colours, green, red, or yellow, which, being transparent, suffered the neutral colour to be apparent through them. The subject was then passed through the fire for the first time, and all that was afterwards done for the second and final burning was to hatch and stipple over the foliage and other parts in a darker or finishing colour,

* But there never were so many employed.

with a finer tool, called by the china painters a tracing pencil. Hill was famous for the lightness and delicacy of his manner. This method of doing the whole subject in neutral tint, and afterwards washing it over with transparent local colour, is identical with the practice of Paul Sandby, and all the first water-colour painters, and was also the mode adopted by Sandby's great pupil, the late J. W. Turner. It gave softness, and that attractive quality is absent in the specimens of contemporary ornamentation of ceramies.

The reader will desire to know the secret of composing the material for making porcelain or china ware, and that we will now supply from the notes of a contemporary of the Derby works enterprise, whose descriptions are full of intelligence and observation, and whose chemistry, while novel and instructing, savours of practical working :—

"Porcelain is an artificial substance of a middle nature between earthenware and glass. It resists fuseing in the fire, when perfect, equally with the first ; and bears in like manner a sudden change with regard to heat and cold. But at the same time it has to a certain degree the transparency, and entirely the close and even texture of the latter.

"The principle on which the substance of china is formed is as follows :—There are some kinds of earths which, being exposed to a strong heat, will after some time fuse or melt, and acquire the nature of glass ; whilst there are others, on the contrary, that resist entirely the action of heat, and remain unaltered by it ; at least with respect to that degree which can be applied by means of furnaces, or such artificial fires. The first of these are called vitrescent earths ; the others apyrous.

"Now these two kinds being mixed together in due proportion, they so operate on each other that a matter endued with the properties above enumerated is consequently produced. For the vitrescent earth, though it is prevented by the other from liquefying, so as to become fluid, yet melts to such a degree as to make the parts of the whole cohere and gain a semi-transparency. But the other affords a body which, not having any propensity to melt, hinders a greater liquefaction of the whole by absorbing the fluid formed by the other, and gives, consequently, a proper rigidity or stiffness to the whole mass when hot, and at the same time prevents its gaining when becoming cold that vitrous grain or texture which would render it more transparent as likewise brittle, and apt to crack or fly on any sudden change with regard to heat or cold. . . . . .

"The following composition will produce wares which will have the properties of true china, if they be rightly managed in the manufacture :—

"Take of the best white sand, or calcined flints, finely powdered, twenty pounds ; add to it of very white pearl ashes five pounds ; of bones calcined to perfect whiteness, two pounds ; temper the whole with gum-water dissolving the gum-arabic or senegal, in water. This requires a considerable force and continuance of heat to bring it to perfection ; but will be very white and good when it is properly treated."

The narrator sets forth his observations derived from visiting China works. That at London (Bow) he had seen eleven mills at work grinding pieces of Eastern China, and adding thereto some fluxing or vitreous substance ; work it up anew : he says the ware could never be white or free from flaws and bubbles, and therefore lacked tenacity : that another manufactory (Chelsea) produced the very opposite kind ; very white, and of texture admitting the most delicate casting or modelling ; the composition resembled glass, liable to break or crack, and unable to bear the test of boiling water : that another factory at Worcester had produced cheap wares, very light, of great tenacity, and that could bear hot water better than real china. He concludes by saying that although Dresden and St. Vincennes are esteemed the only factories in Europe that have approached perfection, there is no reason in supposing that we ourselves will not be able in time to master this as we have other manufactures.

Before going further on the subject of the workers, the practical man would like to have M. Réaumur's notes "On the Conversion of Glass into Porcelain."

"The principle on which the transformation of glass to porcelain depends is this, that, as was observed before, porcelain being a glass imperfectly vitrified, it may be produced either by making such compositions as will induce heat, and vitrify only to a less degree, without a proportionable progression beyond that point to a more perfect state, or by reducing such glass as is perfectly vitrified back to that state."

Réaumur established his invention on this principle, and by experience proved its practicability, not only for fine, but with the coarsest green bottle glass, and the manner of effecting the change is thus described :—

"The glass to be converted into porcelain should be first wrought into vessels or other pieces by the methods commonly used for glass, and when they are so wrought they should be put into eassettes such as are used for burning china.

"Along with the pieces of glass must be put a mixture of equal parts of plaster of Paris and fine sand, so as to fill the cassettes, not leaving even the least interstice. These cassettes are then covered one on another until the furnace is filled. They are then furnaced, and after burning a sufficient time, and the cassettes become cold, the pieces are taken out ; they are no longer glass ; they are beautiful china that can be painted or otherwise graced according to the Eastern formula."

Mr. Haslam writes : "The Derby Factory was not more distinguished for its china ware than for the artistic figures which were modelled and produced there. China figures are cast in separate parts, in moulds made of plaster of Paris. First, the figure is modelled in a tough clay, called modelling clay. The head and limbs are then cut off from the trunk, and a separate mould made of each part. China clay, mixed with water to the consistency of cream, is poured into these moulds, which quickly absorb the water out of the clay immediately in contact with the plaster mould, and before there has been time for the absorption of the whole of it ; that part of the clay which remains in a liquid state inside the larger parts of the figure, is poured back again, thus leaving those parts hollow. This considerably lessens the risk there would be in firing them if perfectly solid. After the different parts are cast in this manner, they are sharpened up with a modelling tool, the marks left by the mould removed, and each carefully joined in its proper place. This is done with the same material, so that, when burnt, the whole is fused together, and it is difficult to see where the parts have been united. To do this properly skill is required, and some knowledge of the human figure."

The celebrated Derby biscuit-body, which is as remarkable for its excellence, as was the talent shown in the modelling of the numerous beautiful groups and figures which were made in it, is not so old as some imagine. As before stated, bones enter into its composition, and that material in porcelain is said not to have been known in the last century. During the last days of the Derby works, the genuine biscuit-body gradually died out ; by some means the exact recipe had been lost, and there had even been a depressing difficulty and cost in the work of production, which disheartened the workers. It had been the custom to burn the biscuit figures in the same kiln with the useful ware ; but, as they required a less degree of heat, they were placed near the bottom, and in the front of the oven, where the temperature is always lowest. This answered well enough until the china body gradually assumed a harder character, and consequently required a greater degree of heat. This did not work well for biscuit figures, for, although it was customary to support all the parts with props of the same material, and the shrinking in the burning would of course be proportionate, the figures were often melted out of shape and spoiled. It was, therefore, decided to discontinue making biscuit figures in that particular body rather than construct especial kilns. Thus the figures and groups came to be made of the ordinary china body, which, although slightly altered in order to take off the dry and somewhat harsh character of porcelain before glazing, did not possess the ivory-like colour, or the semi-transparency, of the true Derby biscuit ; the figures have in consequence a whiter and more chalk-like appearance. It was the peculiar quality of the frit, and the large amount of it which was employed, that gave the beautiful character to the Derby biscuit figures ; and it was the soft nature of the frit which made the firing so difficult, and produced serious losses, that led to the whole scheme being discontinued.

Kean is said to have been the Derby workman who discovered the frit, of which a quantity remained at the factory after Kean's time, when one Mountford, who had taken an energetic position in the Derby works, moved from them, and was in a situation in the employment of the late Alderman Copeland at Stoke-on-Trent, where, although he did not recover the lost secret, he accidentally discovered the beautiful Parian body, which has been of enormous profit to employers, but for which Mountford not only reaped no benefit, but narrowly escaped losing the reputation of the discovery, which was assumed by the art-manager of Copeland's factory. However, after a brisk controversy, the honour fell to the right man—the workman, and not the pseudo scientist.

We have in the early notes on this subject referred to the custom of the workers having their own mark, especially in these figure-makers and modellers. There is much confusion respecting these marks, but enough is certain to give value to their productions, if such extrinsic claim availed. At Derby a system of numbering became popular, but these numbers were not consecutive, when several of one pattern had to be produced. They repeated the original numbering, and hence we have no

certain knowledge of how much work emanated from the old factory; but we know it must have been many thousands more than are counted by the marks. These were of the most varied forms, consisting of every conceivable variety of stye and subject, as Gods and Goddesses, Syrens and Tritons, the Muses and the Senses, Arts and Sciences, figures representing the passions and the virtues, monks and nuns, portrait statuettes and busts, theatrical, grotesque, and sentimental figures, birds and animals of every kind, savage and domestic.

In recognising the art and skill of the workers in the Derby factory and that of the men it absorbed from Chelsea and Bow, it would be uncandid not to express our belief that eminent men often accepted commissions. Mr. Haslam quotes from the Duesbury accounts the payment of £75 4s. 9d. to John Bacon, the celebrated sculptor, for models executed by him in the year 1769. Nevertheless, the factory had its own men of fame. Spangler and Stephen excelled in mythological, historical, and classical subjects, such as Nymphs awaking Cupid by tickling his ear with a straw; Bachantes adorning a statue of Pan with wreaths of flowers; three Nymphs, who, having bound Cupid, are pelting him with flowers. The modelling of these and of the others is of great excellence. One need not be surprised to learn that in many particulars the current semi-pastoral, or so called pastoral, style is adopted; purchasers would have it so. We should not expect Minton to issue modelled peacocks, surrounded by flowers or theatrical statuettes of the period; but we must award our admiration of workmen like the brothers Key, employed by Daniell afterwards, and Minton. Dr Syntax, George IV., Napoleon, Liston, Madame Vestris, and a great many other subjects are included in their list. When these were made the price was very small—6s. or 8s. in some cases—but they are now very valuable. Samuel Keys made a pair of large figures—one of Innocence and the other of Hebe—28 inches in height, and richly decorated in colours and gold by his father, assisted by Leonard Lead. Early in 1875 these were offered at Christie & Manson's, but were not sold, the highest bid of £215 not being thought enough.

Mr. Duesbury purchased the Chelsea works, and ultimately broke them up. After many vicissitudes and much prosperity, the old concern at Derby has departed, leaving a memory, however, that will not be allowed to die.

Chemistry applied to the Arts, Manufactures, etc.

ABSTRACTS FROM FOREIGN PERIODICALS, TRANSACTIONS OF SOCIETIES, ETC.

IN another part of this number we have inserted an important paper on Steel Castings, and as a correlative thereto another of equal importance is supplied by Mr. Riley. They should be read together because of their bearing upon each other, and from the intrinsic value of both in the existing phase of those branches of knowledge.

On the introduction and use of spiegeleisen for the manufacture of steel, the accurate determination of manganese, upon which its commercial value depends, became a question of great technical importance. There are two methods usually employed to determine the manganese in spiegeleisen—one known as the direct, the other as the indirect. The direct method usually employed is to dissolve the pulverised spiegeleisen in dilute nitric acid (1·20 sp. gr.); when dissolved a little chlorate of potash and hydrochloric acid are added to destroy the soluble organic matter from the combined carbon; this may also be effected by evaporating the nitric acid solution to dryness, and heating, then re-dissolving in hydrochloric acid, the silica may in this case be filtered off and estimated if required; usually, however, the per-centage is so small that it is not necessary to separate it. The solution diluted to about one quart or one litre is then neutralised with carbonate of soda or ammonia until the solution is turbid and the acid neutralised, acetate of soda or ammonia is then added, the solution boiled, the basic precipitate of iron allowed to settle, then filtered. The precipitate is next re-dissolved in hydrochloric acid and the process repeated, the precipitate being well washed to ensure the complete separation of the manganese. To the solution after evaporation, so as to reduce it to a bulk of about three pints or one and a-half litres, two to four cubic centimetres of bromine are added, the solution is well agitated so as to saturate the liquid with bromine; after the bulk of it has dissolved, ·880 ammonia is added in excess, the flask in which the precipitation is made is well shaken, the manganese begins at once to separate, it is then gently heated for about one hour, up to the boiling point, boiled a few minutes, allowed to settle, and then filtered. The precautions to be taken are to have the solution cool before adding the bromine, and to see that the solution is saturated with the bromine, otherwise the manganese is precipitated incompletely as a light brown pulverulent oxide very difficult to filter. The filtration and washing of this precipitate (when ammoniacal salts only are used) can be effected easily in ten minutes, and the whole operation can be completed in five to six hours. Allowing the solution to stand for a night, to separate the oxide of manganese, as frequently recommended, is quite unnecessary. After filtering off the oxide of manganese, the filtrate should be evaporated down to about one and a-half pints, or three-quarters of a litre, and, after cooling, bromine and ammonia added, to see that the whole of the manganese is separated. If the operation is carefully carried out, it is quite the exception to find manganese in the filtrate, very rarely it occurs; if so, it must be separated and added to the first precipitate. After drying the oxide of manganese, the filter is carefully burnt, the oxide added, and heated strongly for a quarter to half an hour, with access of air, either in a muffle, or, if over a Bunsen burner, it is advisable to finish it over a gas blowpipe.

The indirect method depends on the accurate determination of the iron in the spiegeleisen; to this is added 5 per cent. for carbon and impurities, and the difference is assumed to be manganese. The crushed spiegeleisen—it should be in rather fine powder for this purpose—is dissolved in dilute sulphuric or in hydrochloric acid. After complete solution of the metal, the liquid is diluted with recently-boiled, cooled, distilled water, and the iron estimated in the ordinary way by means of a standard sol. of bichromate or permanganate of potash. The sulphuric acid should be diluted with about three times its bulk of water. Dilute sulphuric acid is preferable to hydrochloric acid, as the sulphate of iron does not oxidise so quickly as the chloride. As regards the first method, when it is carefully carried out, and only ammonia and acetate of ammonia used, and no fixed alkaline salts, I believe that it is the most accurate method for determining manganese in spiegeleisen. The quantity of spiegeleisen operated on for the direct method is 15 grains, and I have a table calculated for percentages. In the indirect determinations duplicate assays are always made, taking different quantities, 15 and 14 grains, or in some cases 15 and 12 grains. As to the relative merits of the different stand. solns., I shall consider this and other points further on. Many chemists seem to be unaware of the fact that one precipitation of the iron is insufficient to separate all the manganese. As the results of numerous experiments, I may state that, assuming 15 grains or 1 gramme of spiegeleisen to be operated on, the average error from only precipitating the iron once is about 1 per cent. As regards the indirect determination of manganese, my experience is that the results obtained, when carefully carried out, are as a rule too low. For some months past, the indirect method has been employed on account of the results being obtained more quickly; now there is very little difference, the results being sometimes a shade higher, at others a little lower. The plan adopted to sample the spiegeleisen is to select four to five clean pieces from every waggon of metal; the samples, when received, varying from 20 to 150 pieces, have small fragments broken off each piece, the same weight—weighed roughly—from every piece being crushed together in a steel mortar until it all passes through a sieve with 225 holes to the square inch; for indirect assays a portion of this is more finely crushed. By practice a man soon becomes expert, and I find no difficulty even when so many as 150 pieces are sent. Take last year; the quantity of spiegeleisen represented by the above direct, and about as many indirect, assays was about 10,000 tons, and I am happy to say very few disputes arose as to yield; any that did occur were readily settled amicably, without much trouble. I mention this to show that spiegeleisen may be fairly sampled, and there is no difficulty in fixing a definite percentage in contracts for sale. The cause of the direct assay being higher than the indirect is due to the fact that when pig iron or steel is dissolved in either dilute sulphuric acid or hydrochloric acid, a certain amount of oily hydrocarbon is formed, and soluble organic matter that acts more or less on the stand. solution, thus making the iron too high, and the manganese too low. This error is obviated when the spiegeleisen is dissolved in nitric acid, the solution evaporated to dryness, and heated to destroy the soluble organic matter. The oxides of iron and manganese should then be dissolved in hydrochloric acid, the solution largely diluted and reduced with sodium sulphite. When this method of indirect determination is employed, the results agree very closely with the direct method, as

will be seen by the series of determinations given below; whereas the difference between the ordinary indirect and direct will be seen by the table to average about ·60 to ·80 too low :—

Percentages of Manganese in Spiegeleisen, Estimated by Different Methods.

No.	Direct estimation.	Indirect estimation by solution in sulphuric acid dil.	Difference.
1	19·43	18·70	·73
2	18·96	18·34	·62
3	19·91	19·57	·34
4	20·22	19·62	·60
5	20·89	19·98	·91
6	19·09	18·32	·77
7	20·41	20·03	·38
8	21·23	19·94	1·29
9	21·66	20·70	·96
10	21·47	21·18	·29

Mean difference in 10 assays, ·69.

The indirect determinations in the following table were made by dissolving in nitric acid, evaporating to dryness, and reducing, as above described :—

No.	Direct determination.	Indirect.	Difference.
1	18·56	18·41	—·15
2	17·46	17·57	+·11
3	12·29	12·04	—·25
4	16·13	15·91	—·22
5	18·50	18·83	—·33
6	18·46	18·14	—·32
7	15·69	15·62	—·07
8	14·18	14·22	+·04
9	15·67	15·59	—·08

Mean difference in 9 assays, 0·13.

All the indirect determinations by dissolving in dilute sulphuric acid were made in duplicate, the results given are the mean of the two; the difference in the two assays, as a rule, was below ·20 per cent., and never exceeded ·30 per cent. Although this method—dissolving in dilute sulphuric acid—gives results, when carefully carried out, too low, in practice the error is in some measure compensated for by the tendency of the protoxide of iron formed in dissolving the spiegeleisen to oxidise; this is more especially the case when hydrochloric acid is used, the chloride oxidising more readily than the sulphate. When permanganate is used, hydrochloric acid cannot be employed as a solvent. The great merit of the indirect process is its rapidity. The time required to finish duplicate assays of a sample of crushed spiegeleisen with scientific accuracy, and using every precaution, is less than one hour, and there would be no difficulty in one operator making from ten to twenty duplicate assays in a day, whereas the direct method requires five or six hours to carry it out efficiently. In the indirect method, as the difference after adding 5 per cent. to the iron is considered to be manganese, it is clear that any impurities over and above the 5 per cent. will also be assumed to be manganese, and hence the actual injurious ingredients will be returned as metal. It will be seen that the consideration of the sufficiency or insufficiency of this deduction becomes of much importance. Practically, I may say, I believe the assumption to be a fair one. The question of carbon in spiegeleisen and in pig iron generally is most interesting and most important, and I certainly think it has not received the attention from chemists, and the consideration from practical men, that it merits. It is not my intention to consider the carbon question in this paper further than it is necessary as regards the composition of spiegeleisen. I may state, however, it is an element that is very badly used by chemists. To determine it accurately requires much time and care, and I have no hesitation in saying many determinations that are given are wrong. The method I employ for the determination of carbon is, to dissolve the pig in neutral chloride of copper; after complete solution of iron and precipitated copper, the carbon, &c., is filtered on asbestos, and burnt with oxide of copper in a current of oxygen gas. Carbon determination by colour test for high percentages of carbon are not satisfactory. I hold, and I purpose on a future occasion proving, that the percentage of carbon in pig iron is a measure of its quality—that is, if you have a high percentage of carbon you cannot have any sulphur, and you cannot have much silicon. Phosphorus, I am sorry to say, it does not influence, and this, so far as my knowledge goes, still remains the *bête noire* of metallurgists. Much difference of opinion exists as to the increase or decrease of carbon in spiegeleisen as the percentage of manganese increases. Some assert that it increases with the manganese, others that it decreases. My experience is that the percentage of carbon increases with the percentage of manganese generally, and on this point my friend, M. Gautier, of Terre Noire, agrees with me. In a series of analyses sent to me, Table II., made of the spiegeleisen manufactured at the Krainische Iron Works, at Laibach, in the blast-furnace, it will be seen, according to their results, that the carbon appears to decrease with the percentage of manganese. In a series of samples received from the above-named works, I have very carefully determined the carbon, and my analyses do not corroborate their views at all, although I must admit that they do not very clearly show any gradual increase beyond a certain point. It would be interesting to have a series of careful analyses of ferro-manganese with a high percentage of carbon. I found in 73 per cent. ferro-manganese carbon per cent. 6·324 : possibly the carbon may not always be influenced by the percentage of manganese, still the balance of testimony is, in my opinion, to the effect that carbon increases with the manganese. There is another method that has been proposed for estimating manganese in spiegeleisen, one that would naturally suggest itself to any chemist. The method proposed is to dissolve the spiegeleisen in dilute nitric acid, and evaporate the solution to dryness in a flask, then to heat in to redness; this operation is a troublesome one, and my experience is, that it is difficult to expel thoroughly the last traces of nitric acid. The oxide of manganese assumed to be Mn_2O_3 — this I think rather doubtful—is then treated in the ordinary way with oxalate of soda and sulphuric acid, and the carbonic acid formed determined volumetrically or by weighing. In a second method, the oxygen is determined by adding a known weight of iron wire dissolved in acid, a certain amount of this is oxidised, and that which is left unoxidised is determined by a standard solution of bichromate of potash. Results are given by Mr. Parry and Mr. Galbraith that certainly correspond, and I think with very great care corresponding results may be obtained; still I have found in practice the determination of the oxygen is not a desirable method. I have made a series of careful experiments on the determination of manganese in pure sulphate of manganese; my object was partly to show how perfect and satisfactory the precipitation by bromine and ammonia is, and secondly, to see what errors may occur from insufficiently igniting the peroxide of manganese, and to prove that the definite oxide Mn_3O_4 can be obtained with care, and to show, so far as our information goes at present, it is the only reliable method we have of directly determining manganese. Pure crystallised sulphate of manganese was finely pulverised and dried for some hours at 212 deg. Fah.—no very special precautions were taken to see that every particle of the four atoms of water were expelled, as I only wished to make comparative experiments; the results, however, all very closely coincide with the theoretical percentage, being, as a rule, slightly lower. If pure and perfectly dry $Mn\,SO_4\,H_2O$ were used, the percentage of the manganese should be 32·54 per cent. After heating the Mn_3O_4 in a muffle and weighing, the percentage of manganese was determined by estimating the extra atom of oxygen in the Mn_3O_4 over and above $MnO\,Mn_3O_4 = 3\,MnO + O$. On looking over the table it will be seen that, taking the number of determinations, eleven in all, made on very different quantities of the salt, and made by three of my assistants, there is only one result that is at all low—31·77 per cent. In all these experiments the manganese was always thrown down most satisfactorily, and only in one or two cases on evaporating down the filtrate was even a trace of manganese found in it; the trace was so minute as not to be weighable. In some cases there was an appreciable loss in igniting the Mn_3O_4 in a muffle; I think occasionally errors are made from this cause; the oxide of manganese should be strongly heated either in a muffle or over the gas blow-pipe.

Manganiferous Iron Ores have a complex composition, and they contain elements not usually found in ordinary iron ores. Hitherto the same method has been adopted for determining the manganese in these ores as in spiegeleisen; there are, however, several of the impurities present in the ore which are precipitated with the oxide of manganese, and very materially affect the accuracy of the results. First, I would point out the curious fact that, as a rule, nearly all manganiferous ores contain baryta, many of them, I may say all the Carthagena ores, contain oxide of zinc, and I would also point out the fact that in numerous instances potash is present in a very marked quantity in manganese ores. I was induced, from the composition of manganiferous ores, to think that probably, from the great affinity that oxide of manganese had for baryta that baryta might be found with the oxide of manganese as ordinarily weighed in the analyses of these ores. This has been proved to be an undoubted fact. I am informed that on the Continent the practice is to use acetate of soda, and in cases where I have been asked to act as referee by importers of ore, this point has been urged, the reason assigned being that with ammoniacal

salts, as before stated, all the manganese was not precipitated. That when acetate of soda is used, higher results are obtained, I am quite ready to admit, the cause being that oxide of zinc is precipitated frequently in some quantity with the oxide of manganese, whereas, where only ammoniacal salts are used, only traces are precipated. Take, for example, two cargoes of ore in which the analysis was made by acetate of soda in one case, and by acetate of ammonia in the other.

Cargo A.

	Grains of ore taken.	Mn_3O_4 obtained.	Mn_3O_4 in filtrate.	Insoluble residue in M_3O_4.	$BaSO_4$ by sulph. acid.	Oxide of zinc, &c.
I.	16·465	5·025	·070	·030	·20	·375
II.	17·32	4·92	—	·04	·27	·090

Cargo B.

I.	13·346	4·70	—	·210	·03	·190
II.	15·595	5·16	—	*nil.*	·19	·070

Nos. I. by acetate of soda, Nos. II. by acetate of ammonia.

Errors in Estimation of Manganese.

Cargo A.	Due to oxide of zinc.	Due to baryta.	Total.
By acetate of soda	1·64	·73	2·37
By acetate of ammonia	·37	·90	1·27

Errors in Estimation of Manganese.

Cargo B.	Due to oxide of zinc, &c.	Due to baryta.	Total
By acetate of soda	1·02	1·24	2·26
By acetate of ammonia	·32	·57	·89

I have given in these two cargoes, the errors due to the oxide of zinc, &c., and also due to the baryta. The errors in both cases amount to from 2 to 2½ per cent. The error from the baryta is common to both processes, whereas I hold the other source of error is very small when acetate of ammonia is used. Recently, my friend, Mr. John Pattinson, has stated that the error may be considerable with the acetate of ammonia process. My experience does not lead me to agree with his view. In only one case have I obtained more than ·10 per cent. of oxide of zinc. The difficulty with the baryta is one that can very easily be remedied, although, perhaps, not quite so easily as would at first be anticipated. It would naturally suggest itself to any chemist to add a few drops of sulphuric acid to the solution of the ore in hydrochloric acid; this, one would naturally think, would separate the baryta. The quantity of baryta is, however, so small, as a rule, in the Carthagena ores, that it is necessary to evaporate off the excess of acid, and dilute the solution with water, allowing it to stand for some hours so as completely to separate the sulphate of barium. If this is not done, baryta will be found as sulphate with the manganese, or as baryta in adding sulphuric acid to the hydrochloric solution of it. As a rule, I find it is in the very rich manganiferous iron ores that the baryta is chiefly found. I have had very frequent cases of a difference of over 1 per cent.; this, in a cargo of ore of 1000 tons, would make a difference of £50 in its value—a very serious item. In calcareous manganiferous iron ores, unless some care is taken in precipitating the manganese, a certain amount of lime is carried down and weighed as manganese. In such cases it is desirable to re-dissolve the peroxide after the first precipitation, and re-precipitate it by bromine and ammonia; by this means any lime or other impurities—except baryta—will be separated. I have tried numerous experiments on the Italian manganiferous iron ore, containing much lime, and also in the analyses of blast furnace cinder from spiegeleisen. I found that by precipitating the oxide of manganese quickly and filtering it rapidly very little lime was taken down, and that the second weighing of the manganese only gave a difference of ·30 per cent. less in the yield. If, however, great care is not taken, and if the solution is allowed to stand for the separation of the manganese, as recommended by some, then I think it is quite possible for the estimation to be 1 to 2 per cent. too high. In these highly calcareous ores, and in analysing blast furnaces cinder from spiegeleisen, it is certainly neccssary to test the oxides of manganese carefully for lime, to see that it is practically free from it. Having pointed out the chief sources of error in the analysis of manganiferous iron ores, I would observe that much depends on the method of carrying out the analysis. I feel certain, especially where using acetate and carbonate of soda, I could make my results vary from 1 to 2 per cent., depending upon the different manipulations of the analysis. To others than chemists, the question would naturally suggest itself, that if there are all these sources of errors in analyses, and it would seem that only those who had had considerable experience would carry out the analyses efficiently, that some difficulties would arise in obtaining experienced young men to make the analyses. I may relieve the minds of those who entertain this idea, although I am sorry to say that the results of chemists do differ, and they are to practical men most perplexing. I am happy to say that at some of our larger iron and steel works, and amongst those that have made the analysis of iron and steel a special study, there is a wonderful concordance in the results obtained. This on a future occasion I shall most clearly prove. The mistake is to suppose that it requires a thoroughly scientific chemist; it simply requires one who has had practice and experience in making these analyses specially, and there is no difficulty in training young men with an aptitude for analyses to make these determinations; and I have no hesitation in saying that I have in my laboratories young men who have been with me only eighteen months, who will make the analyses as accurately and as quickly as I can myself, and certainly very much better than the most scientific chemists. The question of sampling the ore is of even more importance than the analysis, as without careful sampling the results of the chemist are valueless. I need hardly point this out to practical men, as their experience in this is quite as large as my own. I purpose confining my remarks to some few points in connection with it. First, I think the samples that I receive are in some cases not judiciously taken. If the ore is not very fine, say that it contains pieces ½in. in diameter, or a trifle more than this, great care is required so as not to send an undue proportion of the larger lumps; if so, the yield will be too high, as this portion of the ore is, as a rule—not in all cases—the richest; any shaking or heaping process tends to throw the lumps on one side. The ore should be thoroughly mixed, and portions taken from different parts of the heap. The moisture question is also an important one. It is urged by some that if the ore is pulverised finely a portion of the moisture is lost. This is undoubtedly the case if the ore is very wet, or if the pulverising takes place in warm weather, or in a warm room, some moisture may be lost. When the ore contains only 4 to 5 per cent., of water, it may be pulverised finely without any appreciable loss. The Carthagena ores are not ores that absorb much moisture from the air, like many other ores. The average percentage of moisture in air-dried ore is about 2½ per cent.: that is to say, assuming the ore to be dried at 212 degrees Fah., and exposed to the air, it would absorb again about 2½ per cent. whereas some highly hygrometric ores, such as Northampton, Lincolnshire, and Leicestershire ores, will absorb as much as 7½ per cent. of moisture in 48 hours when exposed to the ordinary atmosphere of a room in winter. In giving the yield of an iron ore, it is necessary to remember the fact that, after drying, finely powdered ores absorb, by exposure to the air, a considerable amount of moisture. The plan I adopt to estimate the moisture is to open the box or bottle containing the sample of ore and turn it out on to a balance-pan, of which I have several interchangeable in the balance. The weight is made a whole number, to make the calculations more simple, and to avoid error by having complex numbers. The quantity generally sent is from 2000 to 4000 grains; anything below 100 grains is put back into the box, carefully taking it from different parts of the heap. The ore is then placed in a water oven at 212 degrees Fah., and weighed until its weight is constant, cooling it rapidly on a piece of iron. The weight, when warm, is from five to seven grains less on the above-named quantities. An ordinary Avery's balance with gate knife edges, turning with about half a grain, is used, and is sufficiently accurate. The ore, when dry, is sifted through fine muslin—adding that left in the box—the portion not passing through the sieve is pulverised in a chilled cast-iron mortar with hardened cast steel pestle, until it all passes through the sieve. A portion of the ore, after thoroughly mixing, is then pulverised in an agate mortar and placed in the water oven for 1 to 1½ hours, it is then put into a close tube and portions weighed out for analysis. For the determination of manganese in manganiferous iron ores, I would suggest that about 1 gramme or 15 grains of the ore dried at 212 degrees Fah., should be dissolved in hydrochloric acid, the siliceous matter separated by filtration, and the larger portion of the free hydrochloric acid driven off from the acid portion of the filtrate, reserving the washings to make the bulk of the liquid up to about one-third of a litre or half a pint; the solution should be allowed to stand four hours, to see if any baryta separates after adding previously a few drops of sulphuric acid. If any sulphate of baryta separates it must

be filtered off, if not, the analysis may be proceeded with; the solution should be diluted to about one quart or one litre, made neutral, or until the solution is slightly turbid with ammonia, and acetate of ammonia added, the solution then boiled, after boiling allowed to settle and filtered. After filtration, and without washing, the precipitate is re-dissolved in hydrochloric acid, and again precipitated with ammonia and acetate of ammonia. The basic peracetate of iron, after settling, is filtered off and washed three or four times with boiling distilled water, adding each time a few drops of acetate of ammonia to prevent the oxide of iron passing into the filtrate and to facilitate the filtration. The filtrate must be reduced by evaporation to 1½ litres or 3 pints, and when cold bromine is added—2 to 4 cubic centimetres. The solution is well agitated in the flask by shaking until it is saturated with bromine, leaving only a little at the bottom undissolved; 880 ammonia is now added in excess, shaking violently the flask, the liquid is then gradually warmed up to the boiling point for about an hour, then boiled a few minutes, the hydrated peroxide of manganese allowed to settle, then filtered off, and the precipitate dried. The filter first incinerated thoroughly, the peroxide of manganese added, heated with the lid on for a few minutes until red hot, then ignited from a quarter of an hour to twenty minutes over a Bunsen burner, or better in a muffle; if only over a Bunsen burner it should afterwards be ignited over a gas blow-pipe to see that it does not lose weight; a platinum crucible should be used unless the ignition is made in a muffle. The protosesquioxide of manganese ($Mn_3 O_4$) should then be dissolved in a small quantity of hydrochloric acid. If there is any insoluble residue, which occasionally occurs, it should be filtered off, a drop or two of sulphuric acid added to see if baryta is present; if any precipitate occurs, it must be separated; to the filtrate or solution is added acetate of ammonia in excess, and sulphuretted hydrogen is passed through it to saturation. The precipitate (a small amount is universally obtained) is filtered off and weighed. Should this weigh more than ·05 of a grain, or three milligrammes, the excess over and above this should be deducted from the oxide of manganese weighed. I think this small amount should be allowed, as the precipitate occasionally contains traces of manganese, and the filtrate from the precipitation of the manganese by bromine and ammonia also contains a faint trace of manganese. This filtrate, in all cases, should be evaporated down to half a litre, or nearly a pint, and tested with bromine and ammonia, to see if all the manganese is separated. As a rule, either none is obtained or a mere trace. In making duplicate analyses, different quantities should be taken. The above-named method is the one I employ in my laboratory, and there is no difficulty in obtaining thoroughly concordant results by three different operators operating on different quantities of ore. A cargo of ore just completed—Tucker, 19·73; Jarvis, 19·53; Bolt, 19·69.

In the discussion which followed,

The President said the paper was of considerable interest to steel manufacturers generally, as well as to chemists. It appeared that chemists had been in the habit of estimating manganese in spiegeleisen by difference. They said in a given sample of spiegeleisen there was so much iron and so much carbon, and the rest they supposed to be manganese, but Mr. Riley had revealed the fact that the residue might be in great part baryta, silicon, and perhaps half-a-dozen other substances. That might account, perhaps, for the very provoking differences in the steel which was produced, and he hoped that these discussions would lead chemists to give more reliable analyses.

Mr. Bessemer, referring to M. Gautier's paper, said he discovered in the process an old friend come back to head-quarters. In the Exhibition of 1862 he himself exhibited a number of castings in steel, chiefly railway crossings, and also an ingot of 17 cwt., one half of which was turned down, showing that not a single air bubble existed in it. That was produced by the use of silicon and manganese; and in his own process, as was well known, one of the great defects was that occluded gases constantly produced air bubbles, and it was the discovery of the means of getting rid of them that induced him to show the samples at the Exhibition. When he first went down to Sheffield some twenty years ago he was an entire stranger to the ordinary mode of producing steel. Steel melters then stated that some of their ingots would work successfully and perfectly sound, while others were full of air bubbles and worked very badly. The term used in that district to distinguish these two characters of steel were "well melted" and "not well melted." When they put their best Swedish iron into a crucible, if they allowed it to remain only a sufficient time to fuse the metal, the result was a bubbly imperfect ingot; if they allowed it to remain an hour or more after melting, and increased the temperature, it became "well melted" steel. He wished to know what was the chemical difference between the two substances, and with the assistance of some eminent chemists, among others Mr. Riley, he ascertained by taking six or seven samples of badly melted steel and six or seven samples of well melted steel produced from the same iron, that the well melted steel contained a small quantity of silicon. He then began to think that it was the silicon that produced the result, but he was puzzled to know how they could get silicon into their first-class Swedish iron. It turned out that in making the steel crucible a plug was used at the bottom to make the core go into the right place. That plug made a hollow in the bottom of the crucible, and if it was simply patched with clay it would be leaky, so that the men put it upon a little flat plate of clay and threw a handful of sand upon it, and to prevent oxidation of the metal they threw in a lump of charcoal. When allowed to remain an hour or more in the furnace with extra heat, a certain quantity of silicon was produced, and then they obtained a well melted steel ingot. He was well satisfied that that was the explanation, though he believed at the time no steel manufacturer in Sheffield had the smallest idea why he made a good ingot one day and a bad one another. He then sought out a suitable pig iron, and having reduced it to the state of soft malleable iron, instead of fusing spiegeleisen he used an alloy of silicon, and the result was a dead melted metal. Among the persons who visited his works were Messrs. Schneider, of Creusot. Their manager passed four months at his works in order to be initiated into all the little mysteries that had been found out in the course of practice. Messrs. Schneider were supplied with twenty-two sheets of drawings of all the plans that were necessary to inaugurate the process, and M. Schneider, jun., also spent a few days in looking at everything that was being done. Four tons of iron were also sent over to Sheffield from Creusot, and the younger Mr. Schneider and the manager saw it turned into ingots, and worked and hammered, and they took it back with them. They were quite satisfied that they could make iron on the Bessemer process, but they occupied some two years in making a huge shop full of machinery according to the drawings which had been supplied to them. That machinery was completed some six or seven days before his principal patent in France expired, and they kept it standing until the patent expired, and when his little patent came into play they were very much astonished at that, and refused to pay him any royalty whatever though they had his plans, though they had four tons of iron worked, and though their manager had had four months at the works at Sheffield. They utterly refused to pay a farthing, and they were now kind enough to tell the English people how to make solid iron castings.

Mr. Snelus said, while, on the one hand, great credit was due to Mr Bessemer for discovering the theory of the action of silicon in producing sound castings, on the other hand the Terre Noire Company were entitled to the high credit of being pioneers in the manufacture on a large scale of the soft steel which he believed would ultimately supersede copper for many purposes. He looked upon the easy production of sound castings in steel as quite equal in value to the production of soft steel by ferro-manganese. Without knowing what was being done in France he had himself been working upon somewhat parallel lines. It was now well known that burnt iron meant silicious iron. There was no difficulty in getting either silicon or manganese into the iron. In manufacturing soft steel plates, he never allowed a plate to pass without having a tensile strain off it as well as a chemical analysis. For some time he was puzzled at getting high tensile strains from very silicious steel, but he had found out that if the silicon was in the steel without carbon, the steel might be very tough and able to stand a high strain. Too much credit could not be given to the French manufacturers who had explained their process, or to the Americans for the way in which they had pushed the engineering part of the operations. He had heard that some gentlemen imagined that the Terre Noire process could only be applied to the Siemens Martin process, but he wished it to be distinctly understood that it could also be applied to the Bessemer process.

Mr. Bessemer said that from 1862 to the present time he had continued making solid castings, and there were some locomotives now running which he had supplied with steel castings. Their behaviour had been carefully noted, and so far they had proved very successful.

Mr. Menelaus: Do we understand that you have cranks running that have never been under the hammer?

Mr. Bessemer: Yes.

Mr. Hatfield, of Sheffield, exhibited a double-throw crank that had never had a hammer upon it. He said it was entirely due to the silicon.